THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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PRODUCTION ENGINEERS JOURNAL

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CONTENTS

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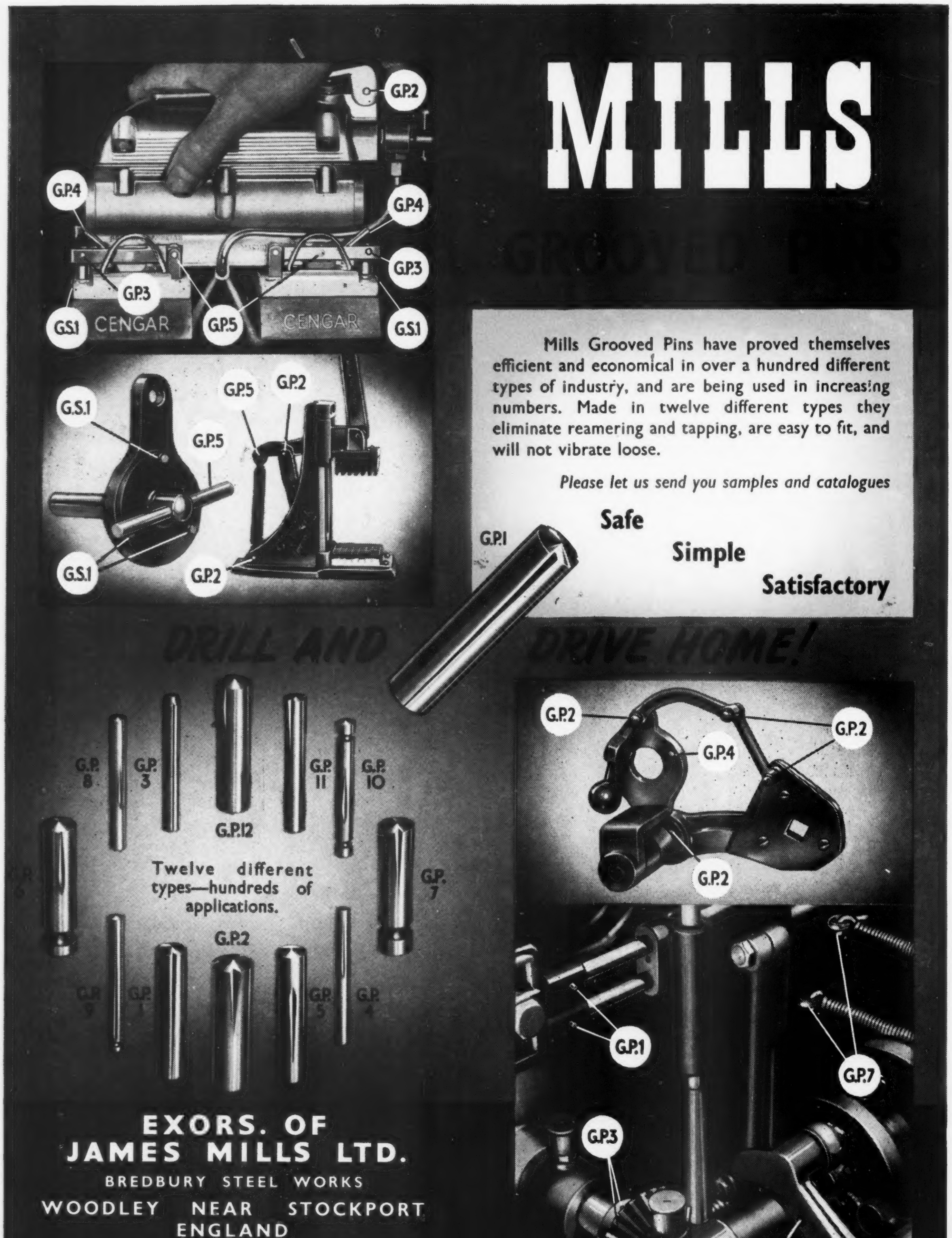
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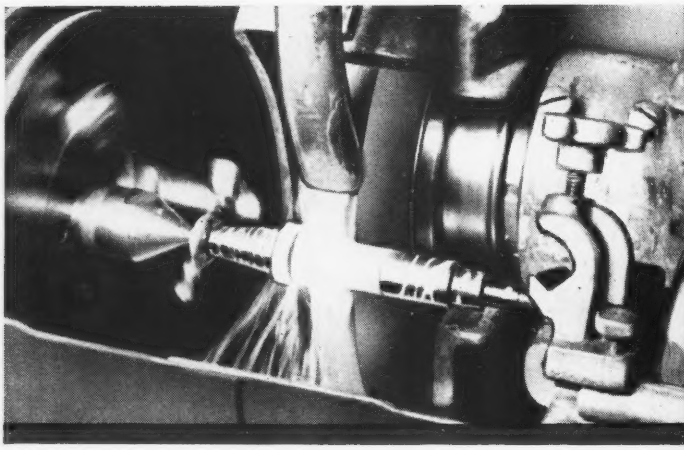

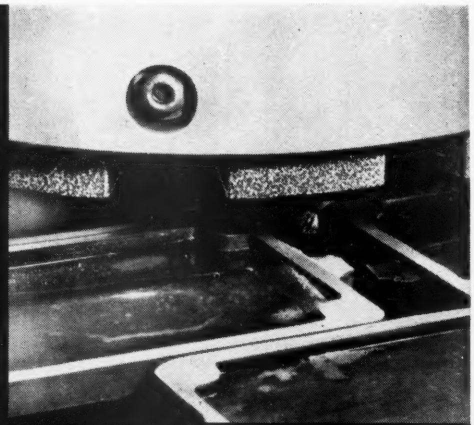

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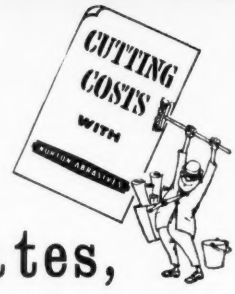

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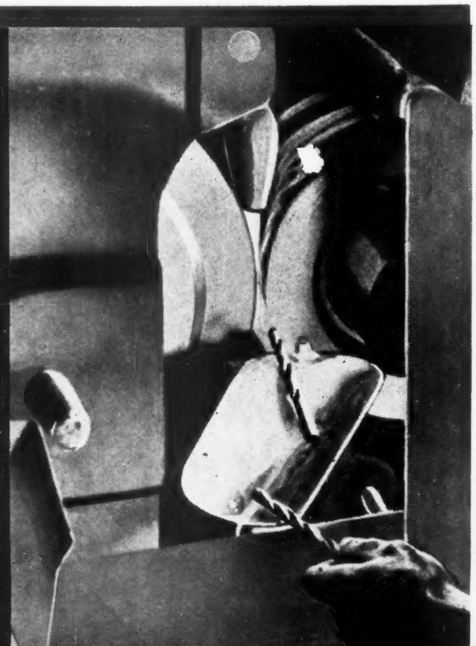

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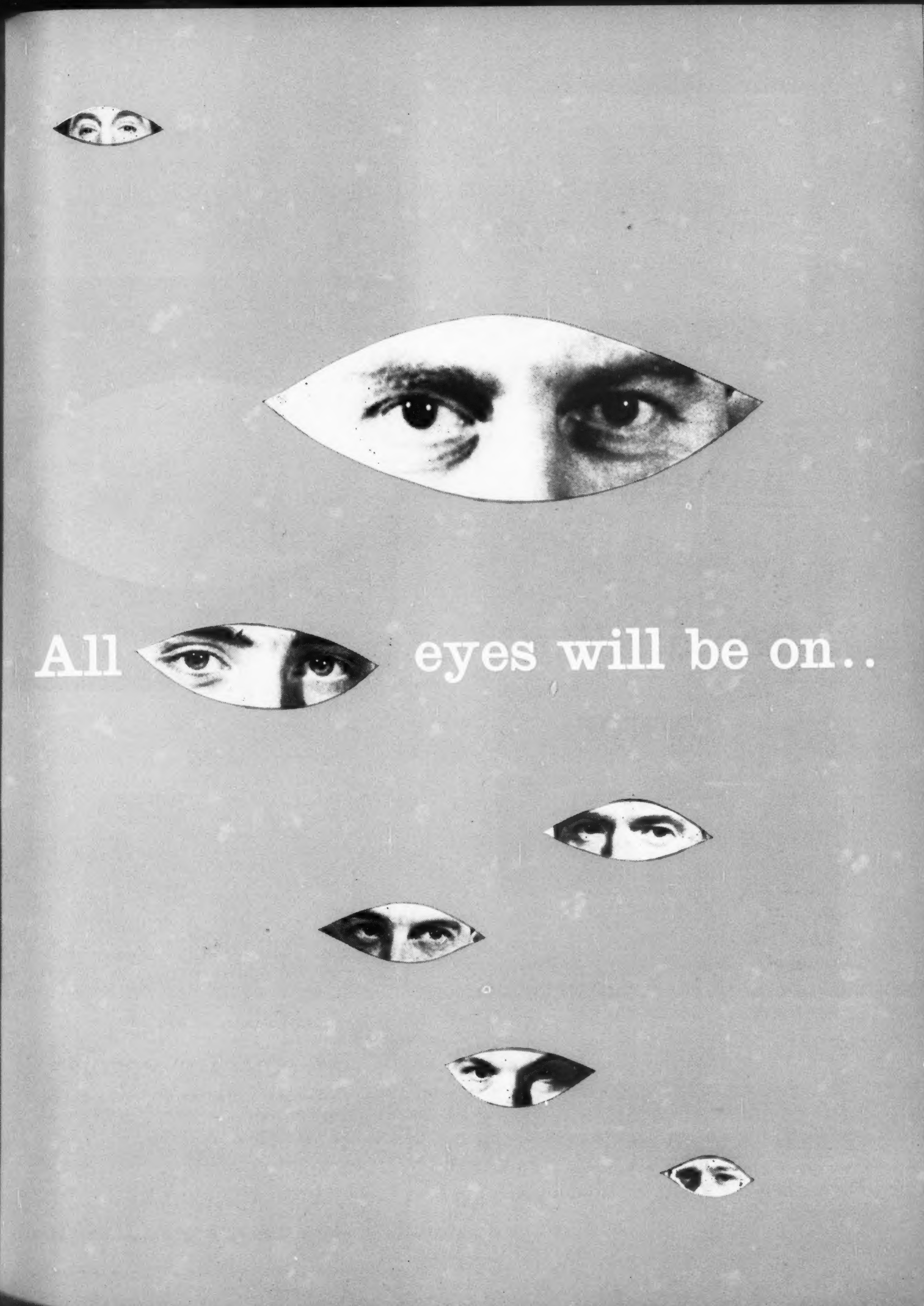
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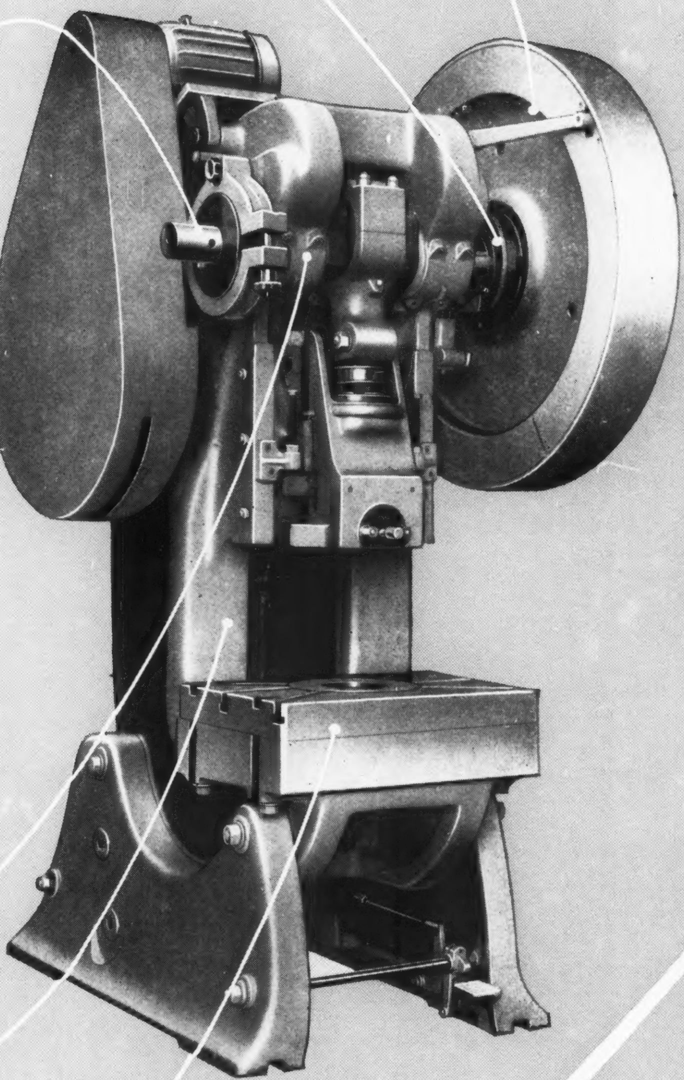

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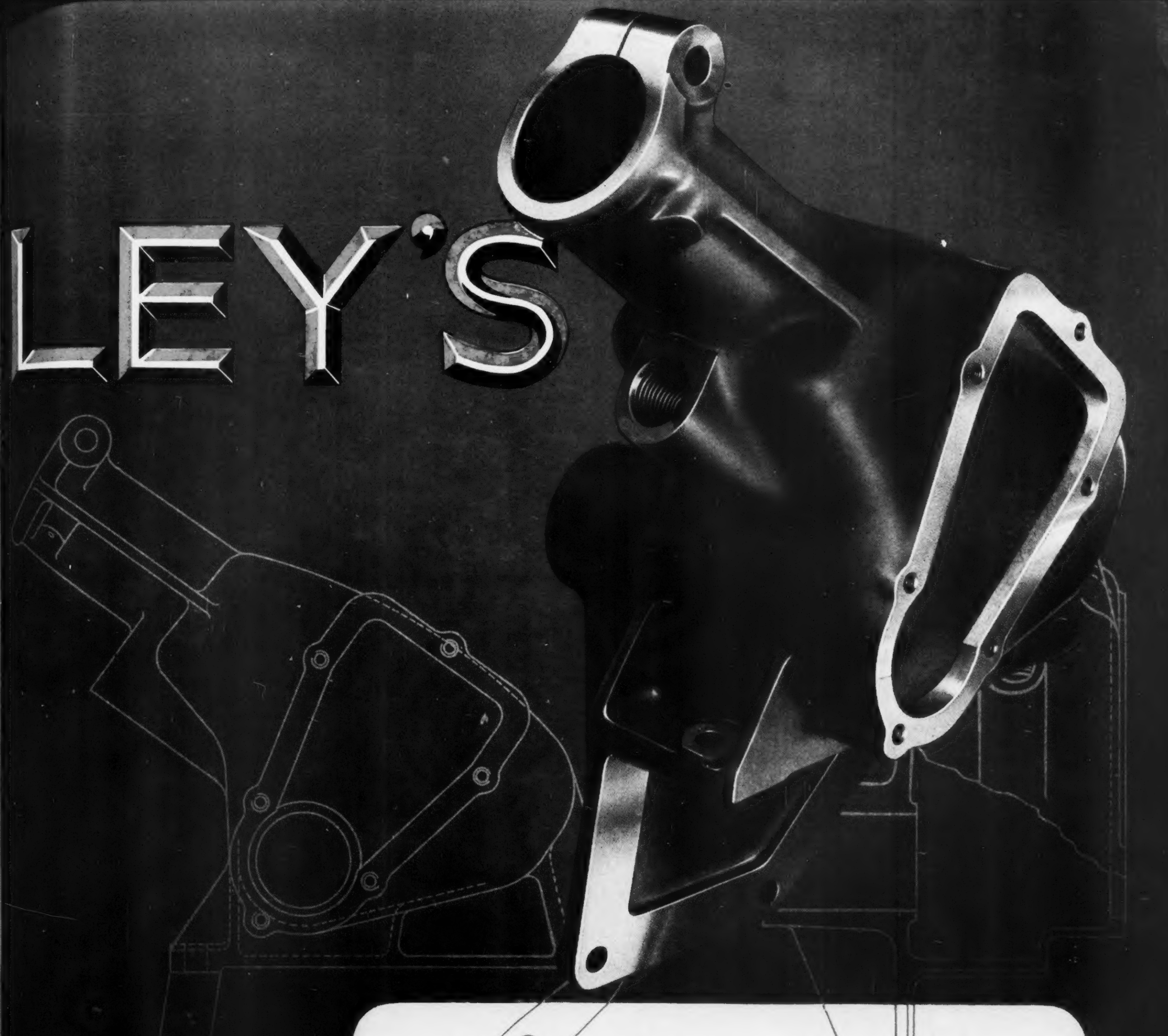

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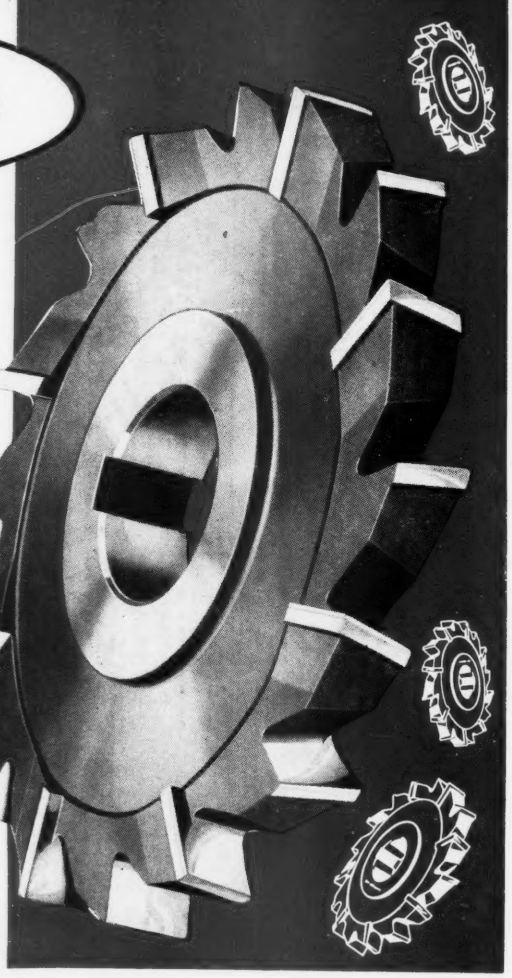

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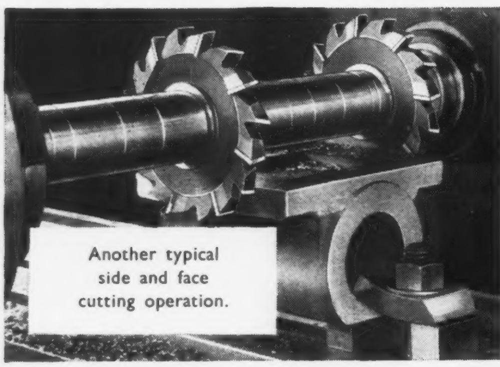

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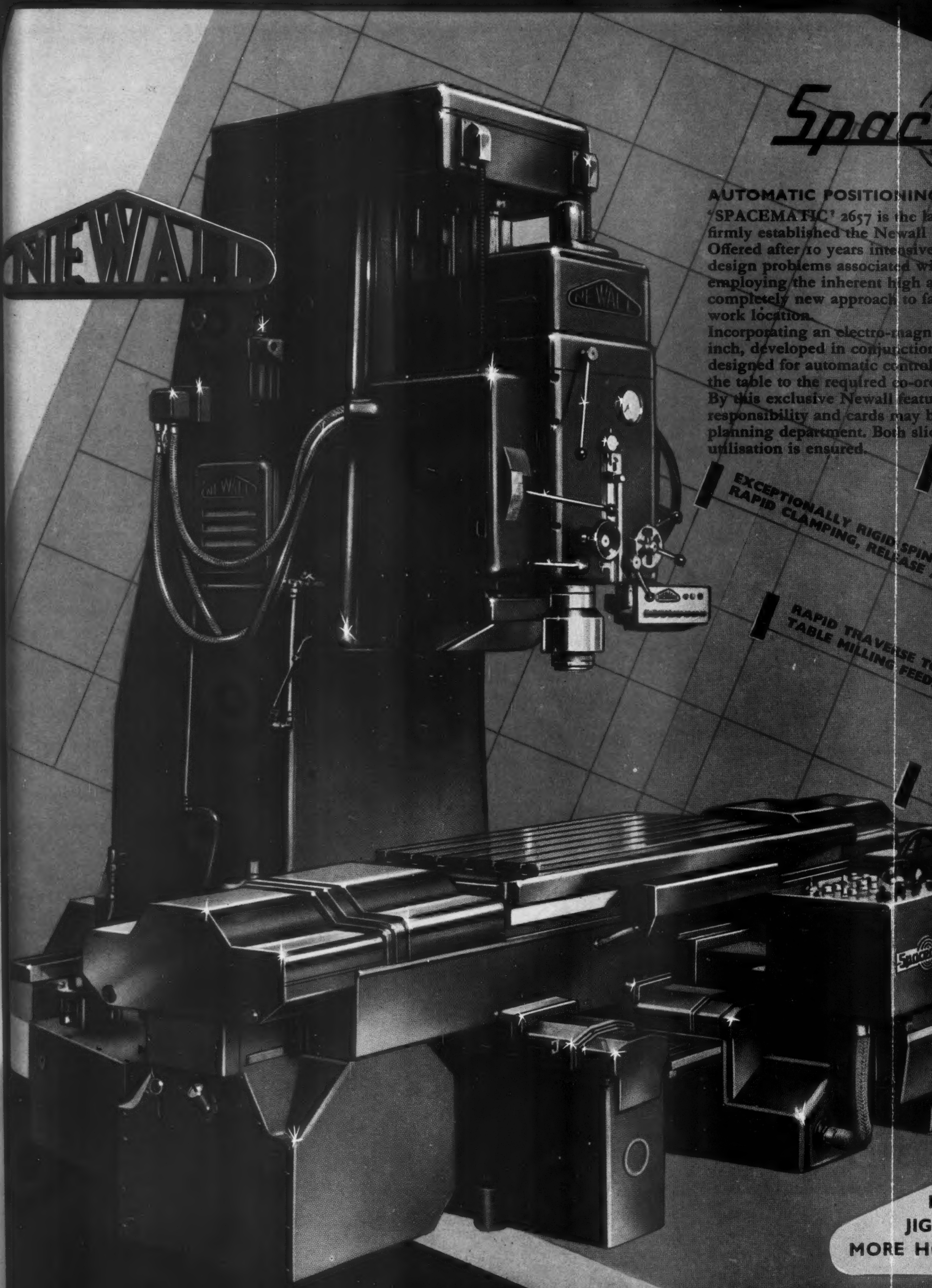
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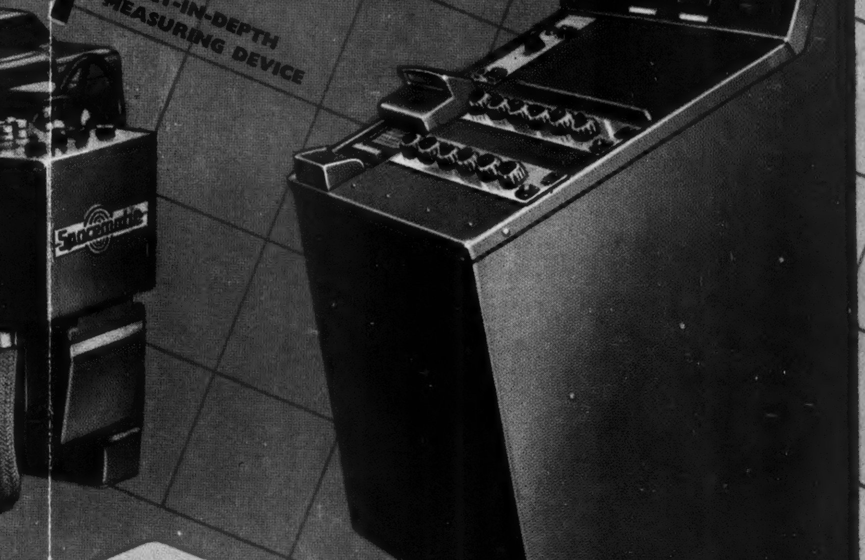

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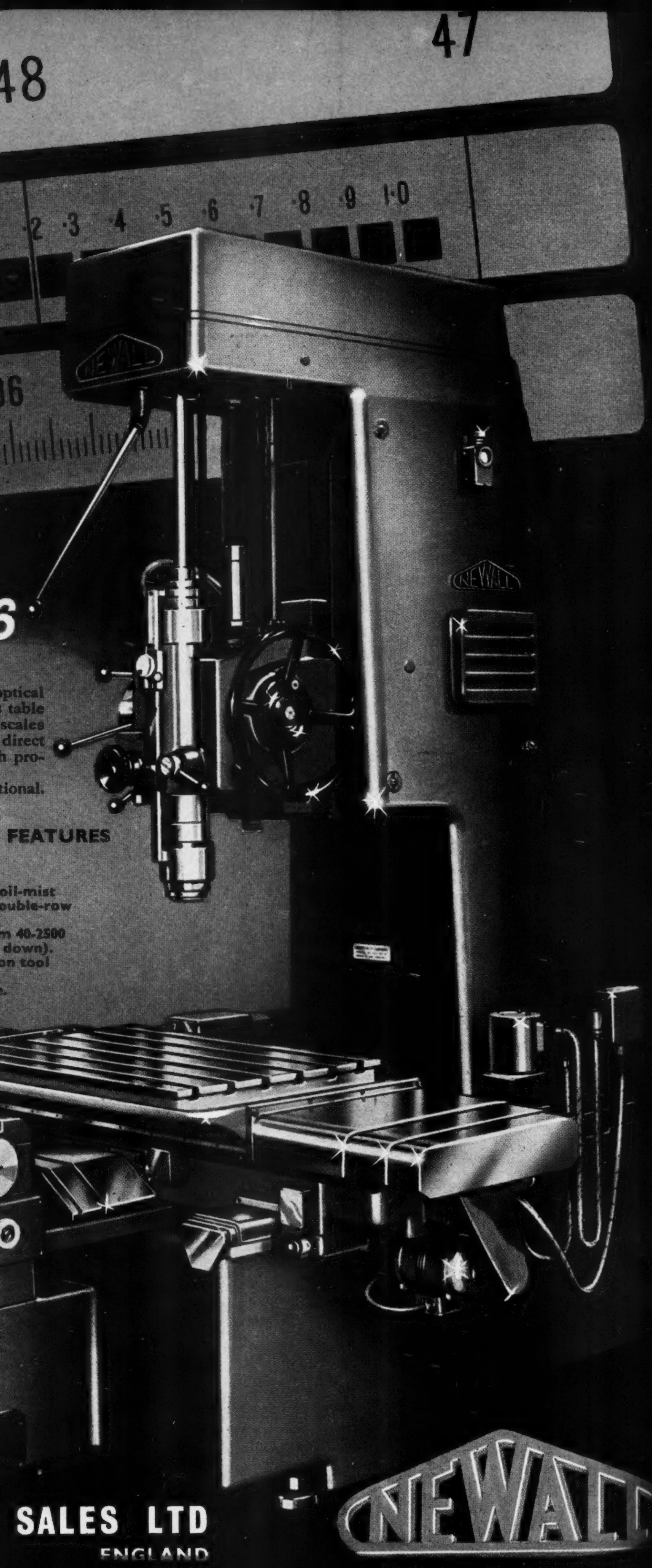

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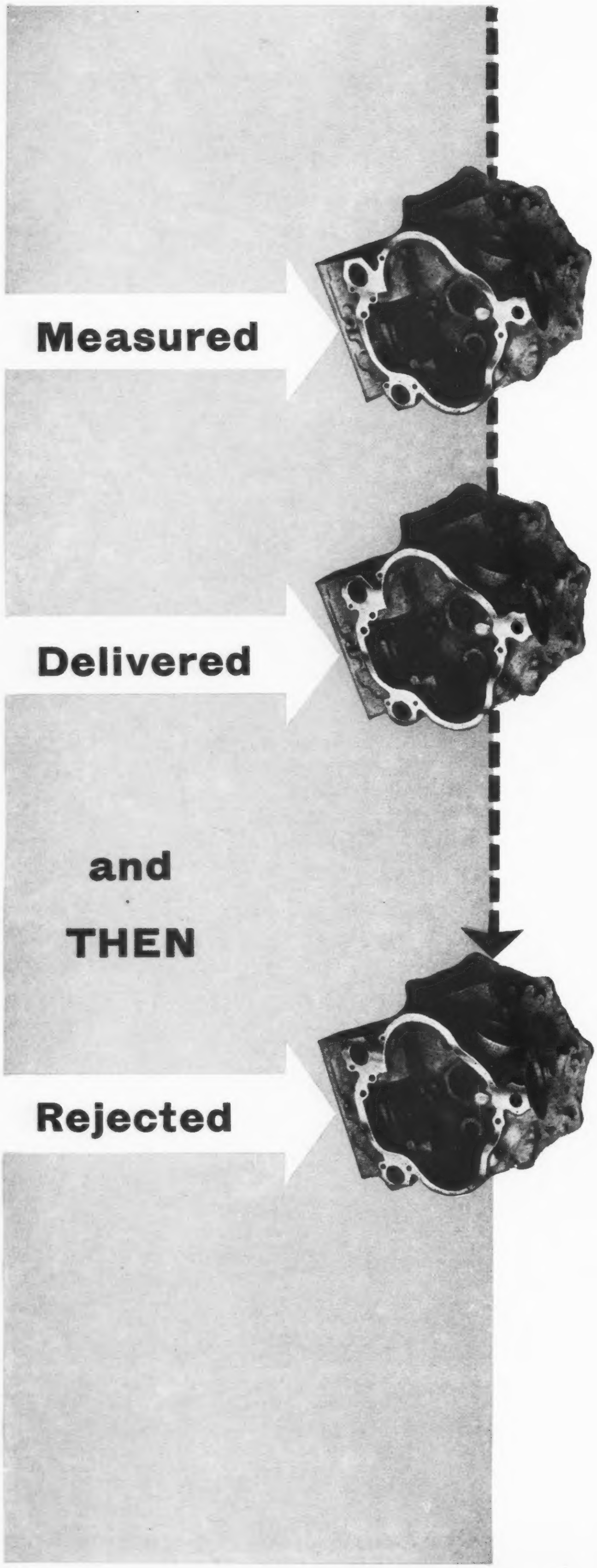
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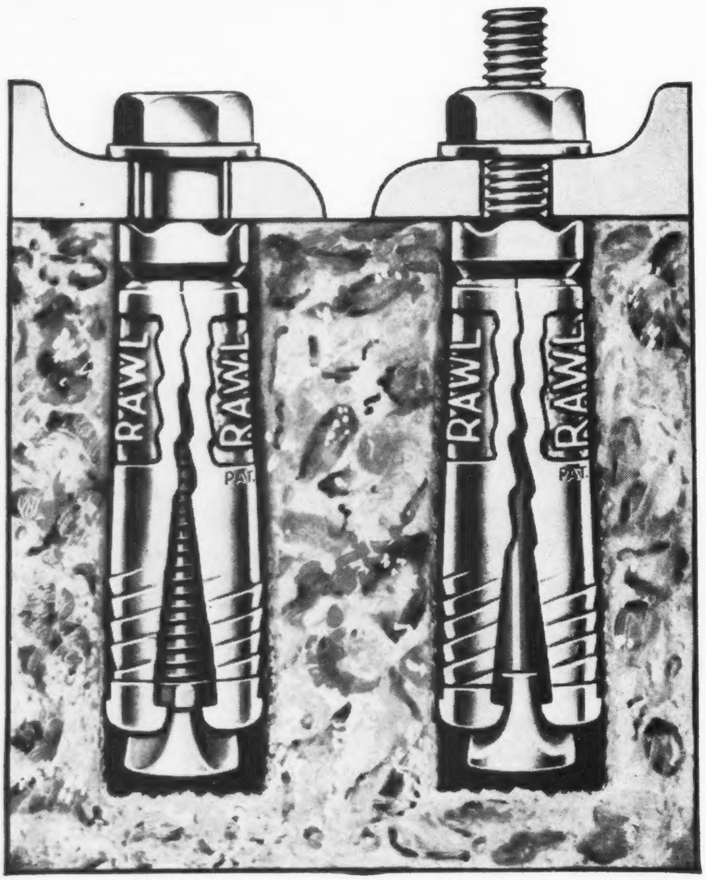

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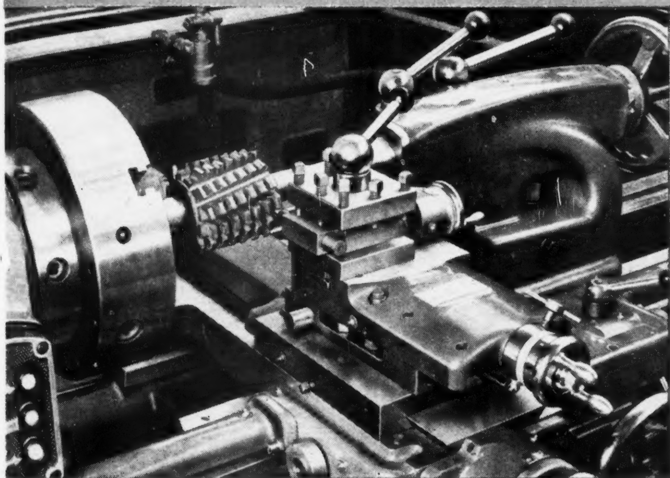

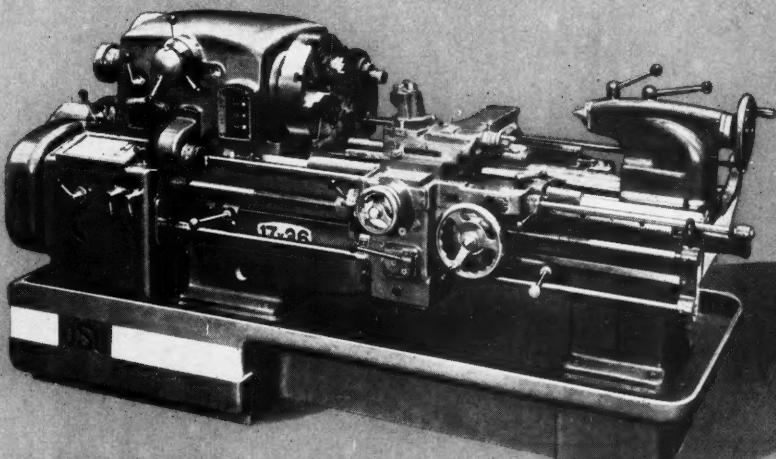

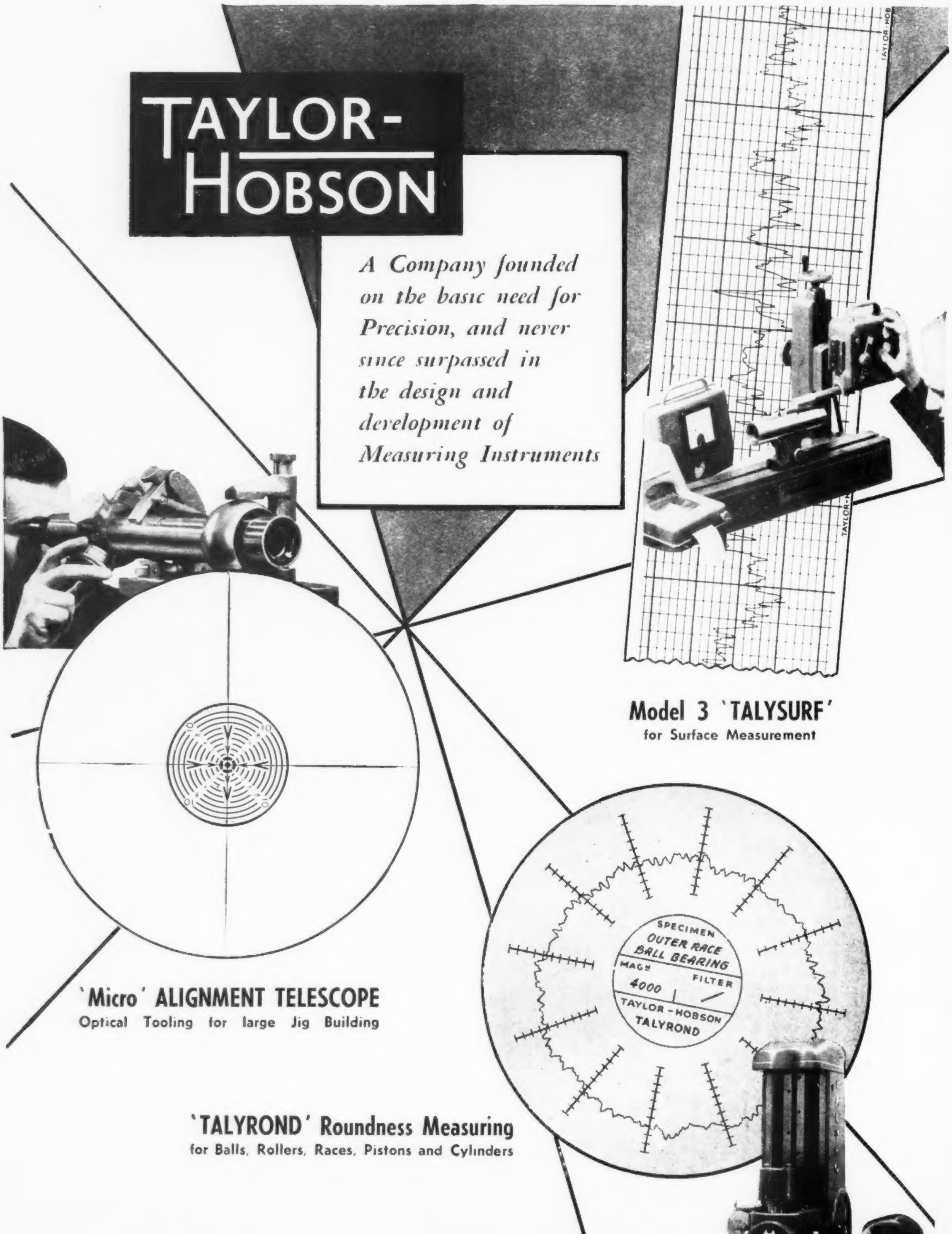
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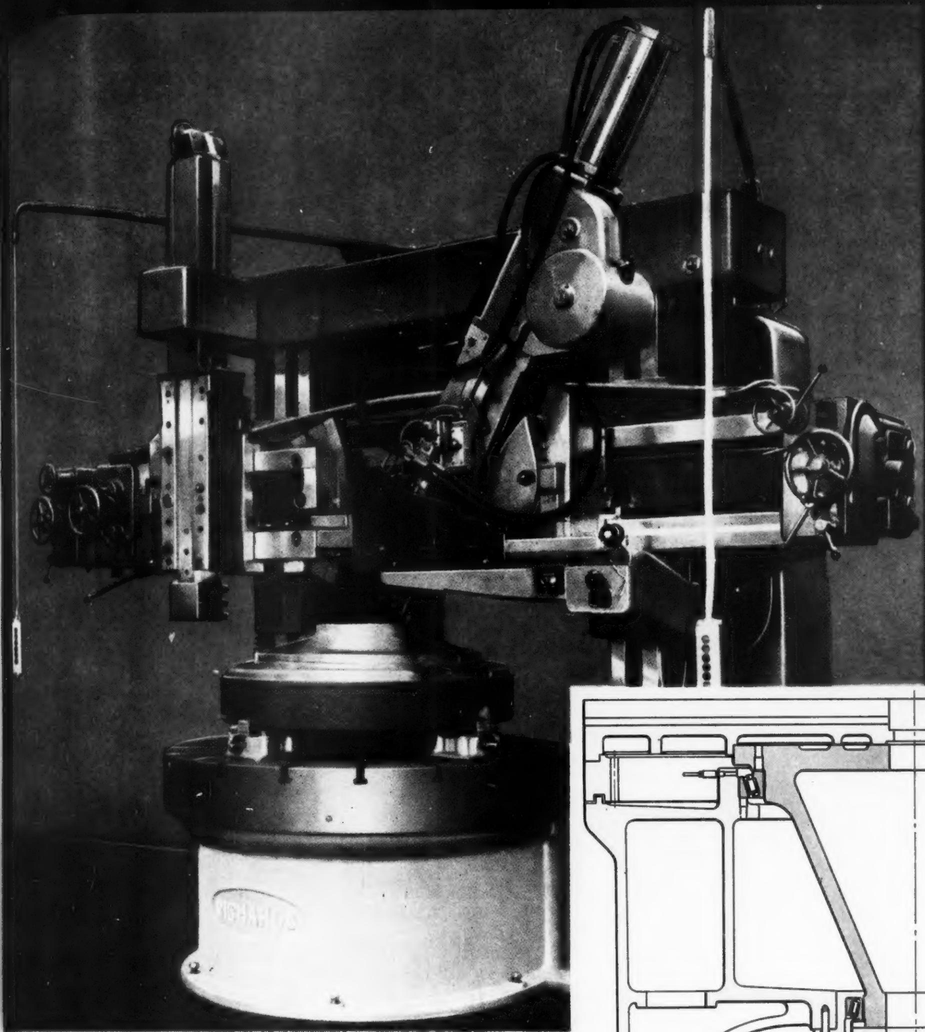

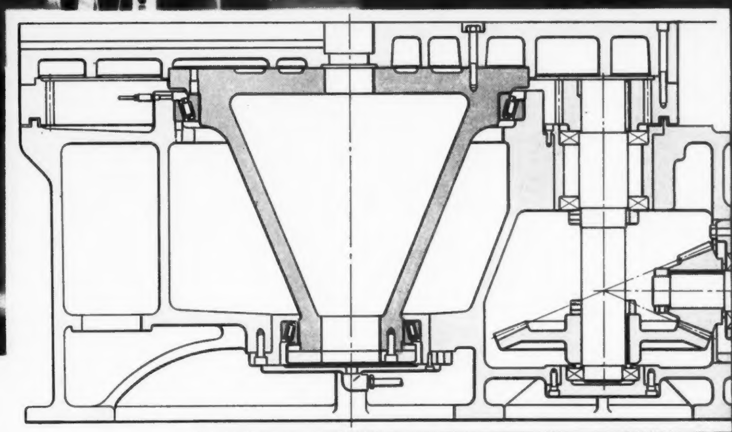

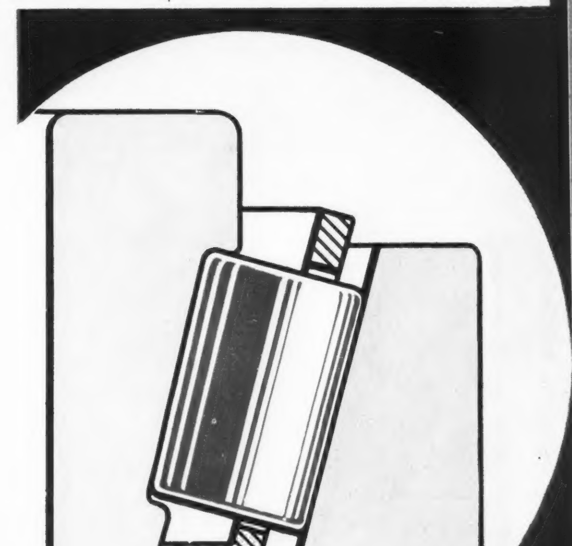

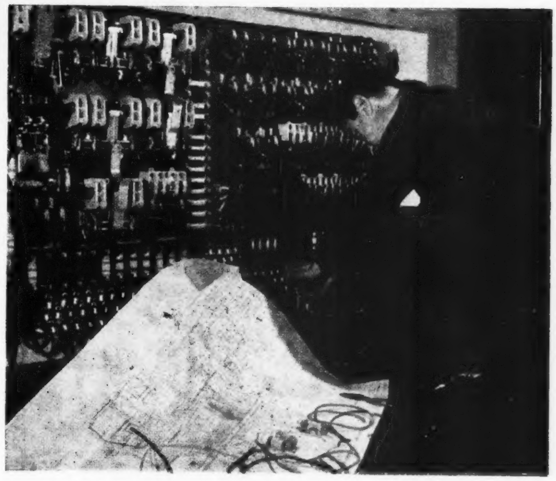

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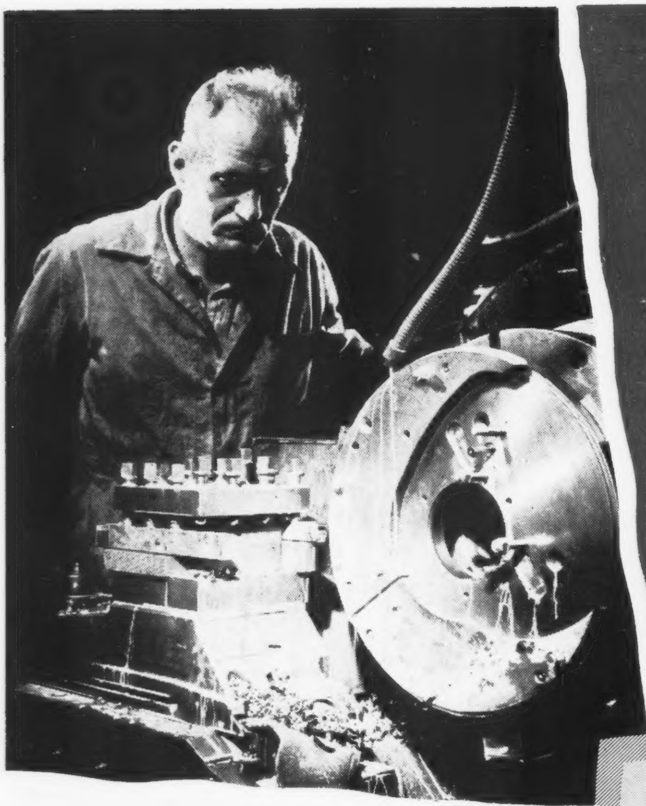

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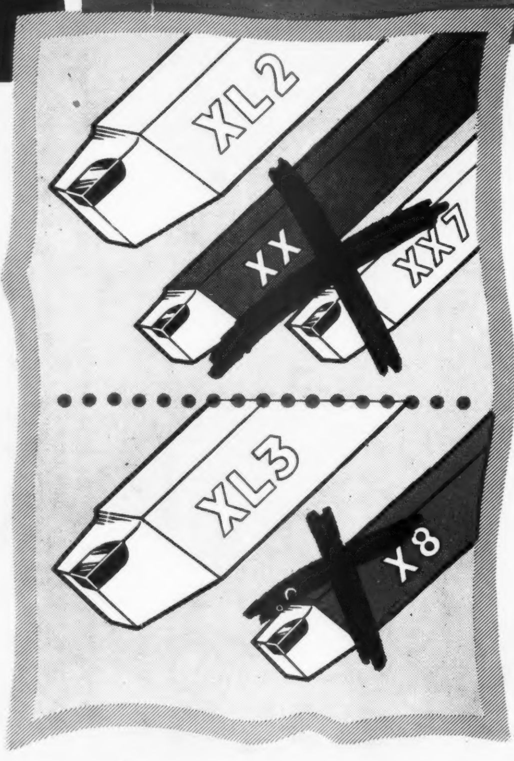

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The Institution of Production Engineers Journal
VOL. 36 NO. 3 MARCH, 1957

1957 Conference on PROBLEMS OF AIRCRAFT PRODUCTION

University of Southampton, 8th/9th January, 1957.

THE **Chairman, Mr. D. L. Wiggins** (*Chairman of the Southampton Section*), extended a hearty welcome to those attending the Conference, and he thanked Mr. D. G. James, the Vice-Chancellor of the University, without whose help and co-operation the Conference, and past Conferences, could not have been held.

The Conference had begun as an idea of the Southampton Section some five years previously, and they were proud that it had now developed into a national annual event. Indeed, this year they could say that it was international. He was sure it would be the wish of those present to extend to Herr Karl Frydag, of Germany, a hearty welcome to Britain and to the Conference.

Southampton was famous for big ships and small aircraft. He was sure the Mayor would forgive him if he confined his remarks to aircraft. After 20 years, the Spitfire was only now being withdrawn from active service, and he defied an electronic computer to calculate the debt that they owed to that gallant little aircraft. However, the Folland Gnat was now in production and, with encouragement, it should be a worthy successor to the Spitfire.

The Minister of Supply had now before him the technical leaders of Britain's aircraft industry, employing some 250,000 people, producing world-beaters such as the Britannia, the Viscount and the Comet. Although the industry could be proud of those fine aircraft, those present appreciated only too well that nothing receded like success. Her Majesty the Queen, however, had recently honoured one of their leaders. In his absence, they congratulated Mr. George Edwards upon an honour so well and truly deserved.

The previous year Sir Roy Fedden had given them what he described as "a little shock treatment", when he had told them that never had so little been done by so many in such a long time. Sir Roy might have done the patient some good, because in 1956 the industry had exported over £100M worth of aircraft and equipment. Surely the Minister's colleague, the Chancellor, must have noticed that in the Aladdin's cave that he called his Exchequer!

This year, man would take his first real bite into outer space with the launching of an artificial satellite, and that, no doubt, would present even further and greater problems, and the theme of the Conference, "New Materials — New Methods", would become all the more vital. If the Conferences helped in any way to put the prize of outer space into British hands, the Institution of Production Engineers would be proud to have played its humble part.

Alderman Mrs. K. E. Cawte, J.P. (*Mayor of Southampton*), extended a most cordial and sincere welcome to the Fifth Conference of the Institution of Production Engineers, and a particularly warm welcome to the Minister of Supply.

They were very happy to be able to welcome Herr Frydag, Direktor of Henschel und Sohn, Kassel, Germany. The shared knowledge of contemporary skilled experience was a privilege to be valued and fostered.

Southampton was very well aware of the great contribution which flowed out of the town to the great and ever-growing aircraft industry. They remembered in veneration that truly great man, Mitchell, and they were very proud that Spitfire aircraft were designed and constructed there.

As a member of the Southampton Education Committee, it would be foolish if she were not gratified at the contribution which that authority was making to help production engineering at its own active and ever-growing technical college, with Mr. F. T. West as its Principal. They were fortunate, too, that the Director of Education in Southampton, Mr. F. F. Freeman, was a man of wisdom, vision and action, and the Education Committee and the college acknowledged with pleasure and gratitude his direction from the very beginning and his keenness to put the college in the front rank as a training centre for production engineers.

With regard to the Conference meeting-place, some of them were convinced that of all the ever-growing assets of Southampton, the University could take pride of place, for there men and women of intellectual promise might seek to advance and perfect their selected fields of study. It was the Mayor's own hope and prayer that they would use that knowledge for the advancement of mankind. Increasingly science played its part in the life of mankind. Greater and greater grew the need for trained personnel in the Institution's sphere. Therefore, there must be a joining of hands between universities and people like those present, for only by knowing what was required could training be given to maintain the high reputation of the particular skills represented there.

It had been reported by the Press, the previous week, that Vickers-Armstrongs had successfully concluded a contract to supply 20 Vickers Vanguard turbo-prop aircraft to Trans-Canadian Airlines at a cost of £24,000,000. To Britain, the dollars deal was extremely important, but she had been even more impressed by the statement made by the President of Trans-Canadian Airlines, Mr. Gordon MacGregor, that the decision to order the Vanguard came after the most exhaustive equipment analysis ever undertaken by the Company. As Mayor of a town which had had a great deal to do with that sort of production, she rejoiced that this country had obtained the order in fair competition. She hoped it would be the forerunner of many others.

The theme for the Conference was "New Materials — New Methods". That might well be the caption for the overall new look of science and industry. The Chairman had stated that in 1956 the aircraft industry exported £100M worth of equipment and that this year, man would attempt the experience of penetrating into outer space. The miracles of brain and hand were growing ever more quickly and moving forward to fresh wonders and ever-widening horizons.

She thanked the Institution for its hospitality, welcomed it to Southampton, and wished it a fruitful and happy Conference.

The Rt. Hon. Reginald Maudling, M.P. *(Minister of Supply)*, said that Ministers of the Crown were always grateful to receive invitations from learned societies and institutions such as the Institution of Production Engineers, which play such a very important part in the economic life of the country. He thought that any Minister of Supply should be particularly grateful to be invited to be present by a body so intimately concerned with the aircraft industry as the Institution when it was well known, as was pointed out last year, that the main trouble with the British aircraft industry was the Ministry of Supply!

Referring to the immense importance of the aircraft industry, Mr. Maudling said it had appeared to him, during the short time that he had been in office, that more exaggeration appeared from time to time about the aircraft industry than almost any other. They were told sometimes that it was deplorably incompetent, wasteful and inefficient. They were told at other times that it was almost sacrilege to criticise the industry. Both these excesses were not in the interests of the industry itself, which he believed to be fundamental to the country, most efficient and certainly most important.

The best measure of the quality of the industry and the fairest comparison was to compare it with that of other countries. Outside the Iron Curtain in the free world there was only one other industry that mattered in aircraft on the British scale, and that was the American industry. There were many brilliant ideas on the Continent of Europe, and those present would hear many from Herr Frydag, but at the moment Mr. Maudling thought it was true to say that the British industry exported more in a fortnight than Continental Europe exported in a year. Therefore, at the present stage of development it was right to compare the British with the American industry to try to assess where we stood.

Broadly speaking, in the development of supersonic fighters the Americans had a quite substantial lead. That was due largely to the fact that in the late '40's Britain was very slow in proceeding with manned supersonic flight, and once a country like America obtained a lead, it was difficult to catch up again. Therefore, for the time being at any rate — he

In this group, photographed at the reception preceding the Conference luncheon, are (from left) : Mr. J. W. Taylor, Hon. Secretary, Southampton Section ; Sir Roy Fedden ; The Rt. Hon. Reginald Maudling, Minister of Supply ; Mr. T. Gilbertson, Southampton Section Committee ; Alderman Mrs. K. E. Cawte, Mayor of Southampton ; Mr. D. L. Wiggins, Chairman, Southampton Section ; Mr. H. G. Gregory, Chairman of the Institution's Council ; Herr Frydag ; Mr. W. F. S. Woodford, Institution Secretary ; and the Rt. Hon Lord Sempill, A.F.C.

stressed that — Mr. Maudling thought that the Americans could be said, in the production of manned supersonic fighters, to have a lead on Britain.

In the bomber field, he believed that the V-bombers now coming off the production line were for their purposes equally as good as, if not better than, anything the Americans were currently producing. Considering what was involved in the production of a modern V-bomber, that was a splendid achievement.

In the civil field, last year one British aircraft, the Viscount, penetrated, and now four British machines had penetrated, against the competition of all the Americas, the dollar market of the North American Continent.

Sometimes people outside the industry did not fully appreciate the immense size of that achievement. Up to now the world had always bought American in aircraft, and all the airlines in the world were traditionally geared to American producers, and to get people to buy British rather than American, it was necessary to offer something very significantly better than the Americans were offering.

So this achievement over the tariff barrier in the case of America, and in this highly competitive North American dollar market, was magnificent.

As the Chairman had indicated, the export achievement of the industry in 1956 was really remarkable. So it could be said that from the standpoint of the most acid test, that of world competition, and in face of all the problems created by the Ministry of Supply, the British aircraft industry had done a good job.

But this was not the time to be complacent, because competition was growing. Not only would American and Continental production grow very fast, but he suspected that Russian competition might become a very serious matter indeed, because they had vast technical resources and they had the ability, wth their controlled economy, to achieve deliveries and quote prices which private enterprise economies would have considerable difficulty in meeting.

More important, the problem in Britain was becoming one of development. He did not believe that here there was any shortage whatever of brilliant original ideas, nor did there

seem to be in the aircraft industry, fundamental production problems. There was production capacity adequate certainly to present and future foreseeable requirements.

The greatest problem, in competing with America and Russia and other large countries, was in the field of bringing the designer's idea to where it could be put into shape and produced in quantity.

Mr. Maudling believed it was right to say that soon it would be found that the total expenditure on development work in the British aircraft industry would be approximating to the total expenditure on production. That was where the balance in the industry was changing, which in itself presented considerable economic problems.

Our advantages, basically, were simply the genius of our designers and the skill of our engineers — nothing more than that. In tying those two together in the process of development from the designer to the finished hardware must lie the secret of our success.

Compared with her competitors, Britain had many disadvantages. She had not, and could not have, test facilities on the scale of the United States. She had not got their weather, which was immensely important for the development of modern high speed aircraft, nor their markets, nor the number of trained engineers. Therefore, she must concentrate on making good those deficiencies in every possible way.

A Remarkable Development

Recently — in the last five years or so in particular — there had been a really remarkable development in test and research facilities available in Britain, both in the Ministry of Supply establishments and in industry, both in private firms and through the co-operative efforts of the industry. That had been, and remained, an extremely expensive business, and Mr. Maudling hoped that those who were firmly pressing for economy in Government expenditure would remember the words of the Prime Minister, that it was easy to be in favour of economy in general, but much more difficult to be in favour of economy in particular.

Certainly, it was agreed that one way in which economies should not be made was by cutting down the development and expansion facilities in the way of such things as wind tunnels, high altitude test chambers, and so on. So far as the weather was concerned, nothing could be done about that.

When it came to markets, there could be no doubt that, both financially and in terms of geography, the British market for aircraft was bound to be limited compared with America and Russia. There was, of course, the Commonwealth, and this connection must be developed in every way so as to expand our market. But even the market within the Commonwealth could not compare in size with the vast market for air transportation that existed in the United States and in Soviet Russia. Nor could Britain put the finance behind these things that those two vast economies were able to do.

There was also the great problem of the supply of trained engineers. Once again, here was a case where this country had woken up, far too late, to the fact that she was being outstripped by competitors in the training of skilled technical people. The Government, the country, and industry were now trying to put this right, by speeding up the training of technicians, but it was necessarily a slow business.

In the meantime, he believed, the best way of handling the comparative shortage of engineering skill was by concentration of effort, and one of the best means was through the activities of an institution like the Institution of Production Engineers and through Conferences such as the present one.

The Most Vital Problem

Mr. Maudling congratulated the Institution on the choice of subjects for discussion at the Conference. Finding new materials and new methods was surely the most vital problem for the future of the aircraft industry, where designers and customers were demanding rapidly increasing standards of performance. In the development of new methods, it was possible to find ways of compensating for the relative shortage of skilled manpower, by ensuring that by the best and most modern methods the work was perfected as far as was humanly possible.

Concentration on Fewer Projects

Finally, it must be ensured that the British aircraft industry was concentrated on fewer projects. If it was a smaller industry than those of our competitors, it made sense that it should concentrate on a smaller range of projects. In the military field at the present moment, we were certainly trying to do that. In the course of the Lord Sempill Lecture, there would be given a good deal of extraordinarily interesting advice on this subject.

(*concluded on page* 199)

CONFERENCE PROGRAMME

Theme : " NEW MATERIALS — NEW METHODS "

(This Journal contains a report of **Sessions I, II, and III.**
A report of **Session IV** will appear in the April issue.)

SESSION I

Chairman : Sir Roy Fedden, M.B.E., D.Sc., Hon.F.R.Ae.S., M.I.Mech.E., F.R.S.A., Hon.F.I.A.S., Hon.F.S.A.W.E.

The Lord Sempill Paper

" CONCENTRATION OF AIRCRAFT DEVELOPMENT " by Karl Frydag.

SESSION II

Chairman : Professor E. J. Richards, M.A., B.Sc., F.R.Ae.S.

" FATIGUE OF AIRCRAFT " by Major P. L. Teed, A.R.S.M., M.I.M.M., F.R.Ae.S., F.I.M., F.R.S.A.

SESSION III

Chairman : J. B. Turner, M.I.Prod.E.

" NUMERICAL CONTROL OF MACHINE TOOLS IN AIRCRAFT MANUFACTURE " by O. S. Puckle, M.B.E., M.I.E.E.

SESSION IV

Chairman : S. P. Woodley, M.B.E.

1. **" THE HOT FORMING, ASSEMBLING AND SERVICE APPLICATIONS OF MAGNESIUM ALLOYS "** by R. G. Wilkinson, B.Sc.
2. **" RECENT ADVANCES IN THE APPLICATION OF RESISTANCE WELDING TO AIRFRAME CONSTRUCTION "** by N. K. Gardner, B.Sc.(Eng.), A.F.R.Ae.S.
3. **" CONTOUR ETCHING "** by A. W. Sheppard.

SUMMING UP

by H. G. Gregory, Chairman of the Institution's Council.

SESSION I

THE LORD SEMPILL PAPER

CONCENTRATION OF AIRCRAFT DEVELOPMENT

by KARL FRYDAG

Karl Frydag is a graduate of the Technische Hochschule of Berlin with the degree of Dipl. Ingenieur, and was during the First World War a pilot in the German Air Force. After graduation his first employment was in the turbine-factory of AEG in Berlin. In 1924 he entered the aircraft industry, in which he worked until the German breakdown in 1945. He was a designer with the Rohrbach Metall-Flugzeugbau Berlin and with Messerschmitt Augsburg. Later he was production manager with Focke Wulff Bremen and Henschel Flugzeugwerke Berlin. He became technical director and member of the Board of Directors of the Henschel Flugzeugwerke, and was with them until 1945. In this position Mr. Frydag had a big influence in creating the family of special machine tools, such as automatic riveters, rubber- and stretch-presses in Germany in the early 'thirties, and this played a great part in the speed at which the aircraft industry was built up in Germany between 1934 and 1938.

In 1943 he was the man in charge of aircraft production as a member of a government board comprised of representatives of industries, each one of whom was responsible to the government for the efficient performance of his particular industry. After the War he joined the parent firm of Henschel & Sohn, Kassel, and is now a member of the Board of Directors. He is chairman of the supervisory committee of the DVL (Deutsche Versuchsanstalt für Luftfahrt) and a member of the supervisory board of the WGL (Wissenschaftliche Gesellschaft für Luftfahrt).

Herr Frydag.

MY Lord, Ladies and Gentlemen,

I am most honoured to have been asked to give an address at the Annual Aircraft Production Conference of the Institution of Production Engineers.

First of all, I would like to express my grateful thanks to the Right Honourable Lord Sempill, who invited me to this Conference.

I first made the acquaintance of the then Master of Sempill in 1926, when I was a designer with the Rohrbach Metal Aeroplane Company, who were doing business with the "William Beardmore Company" in Glasgow.

It was in 1926 that the Master of Sempill paid a visit to our works, and I remember well that we showed him a two-engined flying boat. This was the time of the beginning of all metal aircraft construction, the development of which was pioneered in Germany since 1918, at that time a rather expensive enterprise. The Master of Sempill asked me: "Is that a commercial proposition?" and he continued: "No, I don't believe that it could be". I was flabbergasted. Since that time 30 years with all their progress have passed, and our modern aircraft are much more complicated and much more expensive than that old flying boat. But what would the Master of Sempill have said if we had been able at that time to show him a Viscount, which can certainly be considered as a most successful commercial proposition!

1. The demands made on an airplane nowadays differ so widely from those of that time that the then cost of a plane is not comparable with the present cost.

The older members of the distinguished audience will perhaps remember the three-engined flying boat "Romar". This boat had a flying weight of 20 tons. For the development and the design, the Rohrbach Co. had a staff of approximately 80 engineers and designers, who completed all the design work in five months. Another five months were needed before the first flight took place. This was in 1928. Sir Roy Fedden outlined in the first Lord Sempill Paper what is needed today for a main line civil air liner. I admit that the above mentioned flying boat was rather primitive compared with the modern air liners. But because modern 'planes necessarily make heavy demands on engineering and design staff as well as on financial resources, any country concerned with aircraft production will be faced with well defined requirements.

Sir Roy Fedden told this Conference last year that an American firm estimated the time required for the development of a transatlantic air liner as five years,

and the cost for engineering alone, not including manufacture of prototypes, as £12,800,000. Those are astronomical figures and the staff of engineers needed to achieve this task is nearly astronomical, too. And these engineers are in extremely short supply in the whole world, as only engineers of the very first class can do the job.

It is, therefore, essential to realise that the main requirements with which any country is faced are :-

(a) comprehensive long term planning based on a complete, careful analysis of all contemplated development ;
(b) concentration on a limited number of projects ;
(c) strict adherence to the selected projects and their development to the utmost of their possibilities.

2. When speaking of the development and research of a European country we often draw a parallel with the development in the U.S.A. In financial and technical respects we compare the means of a comparatively small country with those of a continent. Any single country in Europe, faced with all the aspects of development, will not be able to keep pace with the means available in the States. In a separate field, however, when concentrating on a limited number of projects, a single country will certainly be able to compete with the U.S.A. Great Britain has given proof of this with the Viscount and the Comet; the misfortune with which the Comet has met does not make any difference to this. (Great Britain, with the Comet, was four years ahead of the world.)

3. Often, the question is asked whether it is necessary for every industrialised country to have an aircraft industry of its own. People often say: " Buy your planes in the U.S.A. and save your country the excessively high expenses resulting from the development and equipment of research plants ". During the past few years, this remark has also often been heard in Germany.

Such a conception is basically wrong and gives evidence of completely ignoring the many great achievements in the field of research in the aircraft industry. Special stress should be laid on the fact that aircraft industry research fertilises not only the aircraft industry, but all other industries as well. In this respect I make special mention of the developments in the equipment field, such as radar; in the field of machine tools I would remind you of the very high standard of machining technique and the more complicated and special machine tools that have come into being during the first post-War decade of aircraft manufacture, of the increased knowledge of the properties of existing materials and also of the new materials of increased strength and flexibility and of resistance to extreme temperature conditions, etc. A striking example is the construction of a bridge over the Rhine near Cologne. Built for the first time in 1937, it was considered of light-weight construction. During the War this bridge was destroyed, and after the War it was rebuilt, applying, however, the most recent knowledge obtained through research work in aircraft design. The result was that the bridge built in 1954 was of only half the weight of the one built in 1937. Remember the development of internal combustion engines, which was given a strong impetus by the aero engine industry. One cannot imagine a country having a well-balanced industry without the benefit of the knowledge that comes from aeronautical research.

4. I should like to revert to the comparison with the U.S.A. In Europe we have national industries which will continue to exist for a certain time. In the research field, however, we should endeavour to think as Europeans. There are efforts being made, emanating originally from France under the name of "A.I.C.M.A.". These efforts refer to team work in the field of the basic sciences, common erection of test plants, supersonic tunnels, etc. Furthermore, the A.I.C.M.A. recommends mutual planning of research and development in order to avoid duplication of work in the different countries.

We, on our part, encourage endeavours of co-operation. Such an encouragement of European co-operation in the research field is all the more important as we have only a limited number of capable scientists. Some figures are quite suitable to demonstrate the necessity of such a European co-operation; at the same time, they are intended to give a warning of the consequences possible if we do not find in time a way of co-operation.

Western Europe (that means England, France,-Italy, Western Germany, Holland and Scandinavia) is producing each year approximately 12,000 engineering graduates. Great Britain alone is producing 2,800 graduates a year. The U.S.A. produced in 1950 50,000 engineering graduates and decreased to 22,000 in 1955. Russia, however, produces at the present time 60,000 engineering graduates every year. These figures are based on publications by the British Government.

I think that these figures, no matter whether or not they might be inaccurate by 2% or 3%, convey a grave warning to us. They should induce us to look for ways of co-operating with one another more closely than has been the case so far. Should we not find the common way and should we not deal extremely productively with our intellectual potential, our future will see the victory of the East over our industries. In the above figures I have not included China. But this country as well will have available, in some decades, a great number of engineering graduates.

5. It is the urgent duty of the governments of the European countries to do much more than has heretofore been done in the training of engineers, by making available for them scholarships and grants. What so far has been done in this field is little and, compared with Russia, nothing.

6. It is the duty of science, research and industry to deal as efficiently as possible with the technical potential available. They must limit their work to some few definite objectives. If they do so, they will achieve something great. I have already mentioned the outstanding performance that Great Britain has achieved with the Comet and Viscount.

7. The neutral visitor to the Farnborough Air Display is astounded to see the numerous fields covered by the British aircraft industry. In my opinion, which I would like to express frankly, a country of the size of Great Britain is not in the position to complete successfully the many various projects she has undertaken. I have the highest esteem for British industry and, above all for the British aircraft industry, and I have many friends in this country. Therefore, I would ask the distinguished audience not to interpret my words as a presumption, but as a warning given in sincere friendship.

There is hardly any branch of the aircraft industry in which Great Britain is not taking an active part, and one cannot imagine that the engineers and technicians available in this country are sufficient in number to complete successfully all the projects that have been initiated. One should not forget that the development of prototypes alone will not do. Their initial testing is followed by production, which, to be completely successful, swallows colossal sums of capital.

8. Furthermore, there is the time factor. You all know that it will not do to finish some day a certain aircraft. In planning development, one can consider only a certain period during which the development of the aircraft will have to be finished. It is quite possible that a fighter being developed will never be completed, as it may be replaced by a guided missile before it nears completion. This example of the fighter is not theory but, as all of you know, a fact.

9. When saying that the observer is astonished at the great number of fields in which the British aircraft industry is engaged, one should add that in many of these fields there is duplication. Had Germany pursued such a varied development during the years after 1933, she would never have developed any substantial production.

10. The successes the German aircraft industry had in the beginning can be accounted for by the following facts :-

(a) The projects to be developed had been planned ahead in full detail by a small number of very qualified engineers and by members of the German Air Ministry. From the outset this programme imposed severe restrictions on the firms concerned. It comprised the development of only :

two fighters ;
one night fighter ;
two bombers ; and only
three engines comprising one 35-litre engine ;
one 48-litre engine ;
one air-cooled engine.

In addition, there were some few special purpose and transport planes.

(b) This programme was highly concentrated. It was essential that planning covered not only airframes and engines, but that the above programme was based on highly detailed planning of all the accessories and equipment and on the manufacturing preparations for mass production. The scope of the series to be produced had been planned minutely as well.

(c) The aircraft industry then existing in Germany could not have accomplished even this concentrated programme on their own. Planning provided for the following assistance for industry :

For development and research, several test plants were erected and provided with first-class equipment covering all kinds of wind tunnels, including supersonic.

For the engine manufacturing industry, a full scale altitude engine test plant was created which was ultra modern for that time.

Research and development of airframes were concentrated in the works of seven firms.

The development of the above mentioned engines was concentrated in three aero-engine factories.

All firms had to use the same drawing system and the same standards.

The factories of the accessory industry as well as of the light metal and steel industries were also planned in the above mentioned programme.

(d) Special care was given to the subsequent mass production. Apart from the seven airframe firms and three engine manufacturers mentioned, in which all development was carried out, quite a number of mass production firms were established, not of the British shadow factory type, but as private enterprises. All the firms dealing with development and research, as well as those dealing with mass production, had been established in accordance with a defined programme published in advance. My firm, for example, had to erect a works for a monthly output of 100 two-engined bombers.

(e) An essential feature, however, was that all these factories were already working before mass production could be considered. They were given preliminary orders to develop production processes in order to prepare themselves for the work of mass production as was done in England in the shadow factories. If possible, they manufactured during this time not the product of their own design, but under licence products of other manufacturers. The result was that anybody, from the production manager down to the worker, was able to understand completely details of any drawing without referring to the design staff of the firm concerned with its development.

(f) Great value was attached to the equipment of the factories. All factories were equipped with presses for sheet forming up to 8,000 tons capacity, and the aluminium factories had presses of capacities up to 50,000 tons. The development of a great number of special machines, such as automatic riveters, special milling machines, etc., is due to the mass production firms of the aircraft industry.

(g) Financing was effected by the Bank of the Aircraft Industry, which was established for this specific purpose.

This system and this planning functioned perfectly as long as it was adhered to. The development and prototypes planned were finished on the fixed dates and mass production began as programmed. The mass production factories planned for a certain output always achieved it.

11. All this could only have been achieved by the above mentioned concentration of planning and development and the untiring determination of the Government to assist the industry, especially in financing such a gigantic enterprise.

12. *Now comes the great tragedy.* The above mentioned plan worked well up to the end of 1941 and during the first months of 1942. By that time the German air superiority had been overcome and the nervousness of the German leaders increased rapidly. First, this nervousness was shown in the interference of military authorities with armament programmes; interference resulting in substantial programme alterations, increased until it became improvisation. First, they tried to improve the available fighter types to combat the air raids on Germany, which were just beginning. This was quite right of itself. But efforts were also made to introduce these improvements in production without considering the laws which determine production.

Allow me to give the following examples as a warning :-

(a) Had, say, Messerschmitt developed an important improvement, orders were given to change over almost the entire programme to Messerschmitt in spite of the fact that the original programme was planned at 50% Messerschmitt and at 50% Focke Wulff.

Had, say, Focke Wulff developed another even greater improvement some months later, the major part of the fighter production was ruthlessly changed over to this type. Such a change-over was repeated several times. This interference in purely technical and engineering matters came from the supreme military leaders. It was the interference of military men in purely engineering processes, gross interference with production, the consequences of which could not be understood by the individuals making the decisions. Any objections, anticipating the consequences, were in vain.

(b) It was intended to replace the night fighter Messerschmitt 110 by an improved model bearing the designation Me 210 and, later, 410. The change-over had already been accomplished. Because certain difficulties cropped up in the Me 210, which could have been easily overcome, the construction of the planes was definitely terminated. This serious decision was taken by military authorities who were unable to foresee the consequences. To show you the values destroyed by such a change-over, I will now show you a film of the manufacture of the Me 410 wing centre, production of which was started at Henschel's, with an output of 100 units per month.

(*A film was shown at this point*)

The entire plane was produced in an identical manner. The tooling-up had cost some million working hours, in order to be able to carry out production with unskilled labour.

All this had to be scrapped. The great loss in money was by no means the most important, but the loss in time and man-hours available was vital.

(c) An example demonstrating the consequences of splitting up production, that is to say, the effort to do everything despite limited capacity, is the example of the Messerschmitt 262, the two-engine jet fighter. After testing a number of prototypes until mass production could be started, efforts were made to build this plane concurrently with the two fighter types already in production. This was possible only to a limited extent, and brought little success. The right way would have been to stop absolutely the production of one of the piston engined fighter types, and to build in its place the jet fighter; hence, concentration!

A great handicap, though partly inevitable but not kept to the possible minimum, was the fact that in the course of time almost all of the planes being built developed quite a number of alternative versions, meaning that not two fighter types, as planned primarily, were produced, but some eight types differing essentially in vital components. I concede that under the weight of War requirements such variations are one way of increasing the capacity of a basic type. In Germany, we had highly concentrated our efforts; in the beginning we started with two types only. But what will the outcome be if the basic planning is founded on, say, five primary types ? How many variations can you expect in such a case and how do you expect to produce them? These are but a few examples of wrong decisions or dangerous interference.

13. *What was the consequence of this intolerable interference?* The programme primarily concentrated, and limited to few types, was enfeebled by this interference and the introduction of numerous variations and new types. Consequently, the monthly output failed to exceed 2,000 planes by the beginning of 1944.

Eventually, in March of 1944, the higher authorities became aware of the result of their interference and decided to reduce the types to a minimum, and to concentrate production efforts. The immediate consequence was a production increase of more than 100%, namely to 4,800 in September, 1944. This increase was possible in spite of the heavy bombing raids to which the aircraft industry was exposed by that time. This production increase in

1944 from 2,000 to 4,800 planes monthly is certainly the best proof of the fact that concentration on a limited number of types will result in ultimate success.

14. I know quite well that it is easy to criticise the past. This lecture is not intended to be fruitless criticism. All of us are bound to take warning from our experience.

15. You might object: "*Why are we worrying about the history of German aircraft industry during the last War? The situation is entirely different today, and technique and engineering have undergone such profound changes that it is no longer possible to learn from the past.*"

I must emphatically oppose such a view. It is true that technical processes and engineering have certainly altered, but man has not. The lesson I have learnt from the past, based on my experience and the observation of the aircraft industries of other countries, is as follows:-

(a) The aircraft industry should be controlled by the Government and by industry working together. The extremely rapid advance of technical processes and engineering does not allow an administration, say, a Ministry, alone to control such an intricate structure, as in the case of the aircraft industry. Even supposing that such a Ministry includes most eminent technicians, these very technicians will certainly lose in a short time intimate contact with industry. To achieve smooth co-operation between industry and Ministry in planning development and planning production of aircraft for civil and military purposes, industry should also be invited to take a part and responsibility in overall planning. A board of industrialists willing to bear responsibility should, together with the Government, formulate proposals for programme development. Above all, this board, together with the Government, should decide which new developments should be carried out and how the production required for defence planning should be distributed to the different factories.

(b) The main duty of this board should be to make the most economical use of the potential available for research work and development, and to avoid parallel developments as far as they originate only in the special interest of a firm.

Please, consider that before the War Germany was far ahead of the other countries as regards development and research, no matter whether in jet engines, guided missiles, aerodynamics, swept wings or other ideas. But we lost the War in the air partly because at a certain period our original ideas of concentration were abandoned and we wasted our technical potential. I am sorry to say that actually Great Britain is in this extremely dangerous position. All of us will have to defend Europe, and I do not think that the current development in Great Britain will meet the requirements of the N.A.T.O. The ten post-War years show in Great Britain developments covering fully almost any field you can think of; still this country is wasting its great resources because the diversity of the projects which have been undertaken does not permit ultimate success.

I venture to put this question: What would you produce if war should break out tomorrow? If Great Britain does not concentrate her efforts on some limited focal points, her success will not meet with her expectations.

(c) Projects which cannot be expected to yield practical success for any reason should be stopped forthwith.

(d) Greater care should be given to the study of production. Under the present conditions prevailing in technical processes and engineering, and faced with the shortage of labour, the position of a production engineer gains more and more importance. In my opinion, this necessity is not given sufficient thought in this country.

In Europe the production engineer does not enjoy the same esteem as in the U.S.A. There are lots of people who think the production engineer to be a second-class engineer. Nothing is more erroneous than such an idea. Automation, which all of us admire, has been created by production engineers. We all, also in this country, must do everything to train production engineers from among the most intelligent of the coming generation, and not only engineers for research and development.

(e) The demand the development of a modern airplane makes on us is so great from the technical point of view that only a limited number of very large firms will be able to perform such a task. In almost all European countries, as well as in England, there are too many small firms. A way should be found to unite smaller firms by organising working groups, thus creating a powerful and efficient unit.

In this respect I share the view of Sir Roy Fedden, who said before this Institution on the 6th January, 1956: "In order to concentrate our efforts and work efficiently, it is suggested that we should do better with three engine firms and six airframe constructors".

When asked what are the tasks on which Great Britain should concentrate, I shall be at a loss as to what to answer. You will think me presumptuous if I dare as a stranger to make suggestions to you. On the other hand, having saddled the horse, I might as well ride it. This is what I am thinking:-

Great Britain should concentrate her efforts on the following main projects:

(a) First ranks the transport aircraft. This task has also been recognised everywhere in Great Britain to be of top priority. No pains should be spared to push ahead this development in the civil and military fields alike. Great Britain was the first country to produce turbo-jet and turbo-propeller transport aircraft. It will require great effort to maintain the advantage that Great Britain at present has with certain types. The danger exists that the U.S. will displace England from the leadership.

(b) As to the fighters, they should concentrate on two types only. I believe that one fighter with supersonic speed and a long range, and an interceptor fighter are the most imperative needs in this field.

(c) Regarding bombers, British industry should concentrate on the development of a supersonic bomber, whereas the conventional night bomber should be produced under licence according to U.S. design.

(d) In co-operation with the U.S.A. or European countries, greatest importance should be devoted to the large field of guided missiles, either ground to air, air to air, or ground to ground.

This conception does not claim completeness, and it relates only to the decisive development of the aircraft industry.

However, I am sure that if Great Britain concentrates its efforts in such a way and adheres to this or another strictly limited programme, the British aircraft industry will be able to compete even with the U.S. aircraft industry.

My Lord, Ladies and Gentlemen, I have had the honour of presenting to you some ideas which have originated in the experience I have had in the aircraft industry. I shall be greatly pleased, if one or the other of my ideas could possibly give the gentlemen concerned food for thought.

REPORT

Chairman: SIR ROY FEDDEN, M.B.E., D.Sc.

The **Chairman,** opening the meeting, said: I feel it is a great honour to preside at the chief Named Paper of the Fifth Conference of the Southampton Section of the Institution of Production Engineers. As many of you know, this Paper was inaugurated to commemorate the outstanding services to aviation of Lord Sempill, and his long and faithful association with the Institution, of which he is a founder member and past President. I am delighted to see my old friend, Lord Sempill, present today to listen to the reading of the Paper.

As Chairman of the opening Session this year, having stepped into the breach at short notice in view of the illness of the Earl of Halsbury, I find myself in a far more relaxed state of mind than at the 1956 Conference, when I was set the task of delivering the first Sempill Paper, with a difficult and challenging title.

I have great pleasure in introducing to you Herr Karl Frydag, the eminent German aeronautical engineer, who is to deliver the Sempill Paper this afternoon.

I have already stated publicly that now that Germany is a full member of N.A.T.O. we should take every opportunity of collaborating with her on many aeronautical matters, and I should like to take this opportunity of congratulating the Institution upon taking the initiative in this matter.

I have had the privilege of knowing Herr Frydag for over 30 years, and I can state without any fear of contradiction that there is no one in Europe today who is more competent to deliver this Paper. He broke into his university engineering training to become a pilot on the Western Front in the First World War. After the War, he completed his engineering studies and became a fully qualified technologist and later on an experienced aircraft designer. In the '20's he was responsible for some excellent design and development work on the Röhrbach all-metal aircraft construction.

In the '30's he left design work and specialised in airframe factory administration and management. I well remember seeing, in 1937, one of the largest and most modern aircraft production plants in Europe, which he had laid out from the green field, and most successfully managed. He pioneered the design and development of modern stretch, extrusion, and heavy presses for aircraft manufacture. He built up such a high reputation for his production management that at a very critical time, during the Second World War, he was put in sole charge of German fighter production and obtained outstanding results.

Herr Frydag is now back with his old firm, Henschel und Sohn, of Kassel, as managing director, with a staff of over 10,000 people, making lorries, diesel engines, locomotives and modern electronically controlled special purpose machine tools. The two Henschel aircraft plants for which he was responsible are now in the hands of the Russians in Eastern Germany, but Herr Frydag is right up-to-date in all aeronautical developments and is taking a leading part in the aircraft scientific and technical deliberations of his country.

I know that Herr Frydag would not wish me to tell you the following, because he is a very modest man. However, he has in fact made an amazing come-back into the post-war engineering world by pure character, hard work and ability. Chased from pillar to post immediately after the War by the Russians, who wanted to get hold of him badly, he

Herr Frydag delivering the Lord Sempill Paper.

often found himself in some very peculiar circumstances. He told me some time ago that the thing which was most difficult for him to bear after the War was when, having been a senior executive controlling tens of thousands of people on aircraft production, he suddenly found himself for the two or three years immediately after the War with absolutely nothing to do. He had no home, no car and no amenities of any kind ; everything had been left in the Eastern zone at a few hours' notice. In fact, he was glad to bicycle 25 or 30 miles to pick up a sack of potatoes or some other food for his family. He certainly has made a most wonderful return to engineering executive management the hard way.

I now call upon Herr Frydag to deliver his Paper, entitled : " Concentration of Aircraft Development ".

(*Herr Frydag then presented his Paper, which appears on pages* 146 - 151.)

The **Chairman,** thanking Herr Frydag, said : I am sure you will agree with me that we have just listened to a most stimulating and very well worthwhile Paper, from which I believe we can draw a valuable lesson which we might well apply here at home. Apart from the able way in which Herr Frydag has dealt with the technical aspects, I am greatly impressed by what he says about the fact that no country can remain great unless it has in proportion to its size a virile, live aircraft industry.

Although the whole tempo of aircraft design and production techniques has advanced enormously in the first post-war decade, so much so that it would be safe to say that the last 10 years have seen greater changes than in the previous 40, nevertheless some of those very difficulties which Herr Frydag has described, and which bedevilled his country's production during the Second World War, might well be causing similar bottlenecks on our present more complex problems.

I feel it is worth noting that Mr. Harry Truman, the former President of the United States, in a most statesmanlike document, outlined in June, 1947, a somewhat similar state of affairs coming to pass in the United States. He called for an immediate investigation at the highest level, which resulted in that now famous document, the Finletter Report, which came out six months later, and provided an amazing blueprint for future American aviation which holds good today, more than eight years afterwards.

Surely these two important signposts, Herr Frydag's review of why German aircraft production got off the rails during the Second World War, and the Finletter Report, which described how American post-war aircraft production congestion could be straightened out, should make us take heart ? Since it is obvious that we have not lost our technological cunning, cannot we boldly take a few stitches in time where they are needed on production ?

I have been asked to say that it has been decided that there will be no discussion after this Paper. The Sempill Paper is cast on similar lines to the Wilbur Wright Lecture of the Royal Aeronautical Society. An authority is chosen to speak on some facet of aircraft production with which he is conversant. The Sempill Paper will act as a platform from which the specialised Papers, upon which there is a discussion afterwards, will emerge as the main theme of the Conference.

I will now ask Mr. Gilbertson, General Manager of Folland Aircraft Ltd., to move a vote of thanks to Herr Frydag.

Mr. T. Gilbertson, M.I.Prod.E. (*Director and General Manager, Folland Aircraft Ltd.*): I am indeed conscious of the honour bestowed upon me, not only as an executive of the local aircraft industry, but as a member of the Committee of the Southampton Section of the Institution of Production Engineers, whose invitation Herr Frydag has been so kind as to accept.

I should like to take the opportunity of supporting the welcome extended earlier by our Chairman, and say that we most heartily welcome Herr Frydag to our Conference and to our country once again. He was a welcome visitor in other times.

It was with great interest that we listened to Herr Frydag mention and enlarge upon some of the many most topical national and aeronautical subjects of today, all of which have their parallel cause and effect in this country as we know they have in Germany. Especially do I refer to the very high cost of building modern aircraft, coupled with the lack of suitable technicians for research, design and production problems.

Herr Frydag has compared Europe, in which he includes Great Britain, with the U.S.A. and Soviet Russia. It is interesting to note the emphasis given to the suggestion for unity in Europe in respect of major research as an answer to the challenge of Russia. Perhaps I might also add — China.

It is not, however, the possible political aspects of Herr Frydag's Paper that I wish to mention, so much as the all-too-obvious point, the complexity of design, bringing with it colossal production, engineering and machining problems, also the dire need for suitable technicians, preferably with know-how rather than a true scientific background and, finally, that hardy annual, the common presentation of information from design to manufacture by way of drawings and standards. I wish somebody would be a dictator and standardise drawing systems in this country. One cannot possibly over-emphasise this latter feature with its resultant network of liaison between workshops, design and so on.

Coming to the film, in five minutes' photography a wealth of experience was shown. It was a presentation which prompts me to ask all sorts of questions. It is a pity that we have decided that there shall not be any discussion of the Paper. I feel sure that the film will send you away thinking seriously of the wicked waste in tonnage of mild steel used in producing jigs and fixtures which become antiquated and useless before they can be got on to the milling machine. We have had an example of what I think is essential today, a special purpose machine. You can visualise drilling and riveting heads which by means of a little alteration could be coupled together to give you a variable arrangement. Ninety per cent. of the effort in tooling by this method will never be wasted. The fact that the film was taken in wartime is an indication of how much we have to pull our socks up. In that film there is a lesson for us.

Herr Frydag has suggested that, in order to keep up with aeronautical progress, the number of types and projects for research should be limited and also that the industry might have at the head Government control, while still having an industrial board or directorate. He also suggested that in Great Britain there are too many small firms. I am not convinced that all that Herr Frydag suggests would be acceptable to the vast majority of the industry, but I agree with him that it is a very important question which must be thoroughly thrashed out and decisions made accordingly. We must, of course, be careful not to discourage the initiative and effort of the small firms when we do so.

Herr Frydag has also mentioned that there is a possibility that the aircraft industry should not be practised by smaller countries. Here again we agree that it is essential and imperative in this modern age that Governments should do all in their power to assist the industry, not only as a means of keeping abreast of world challenge in civil air transport, so much as because of the fact that the development of new materials and methods in the aircraft industry considerably benefits other industries.

We must heartily agree with the views of Herr Frydag on the need to do everything possible to train production engineers from the most intelligent of the coming generation. There is a tendency at present for those young engineers to be encouraged to enter the field of research and development. A substantial quota must be encouraged to take up production engineering as a career.

To take up Herr Frydag's words, perhaps the Government will supply the horse ; we production engineers are quite prepared to saddle it and ride it.

I should like to enlarge upon other of Herr Frydag's points, but that it not my purpose. I wish to support the welcome given to Herr Frydag and to propose a vote of thanks to him, and I ask those present to show their appreciation of his Paper in the customary British manner.

The vote of thanks was carried by acclamation.

SESSION II

THE FATIGUE OF AIRCRAFT

by Major P. L. TEED,

A.R.S.M., M.I.M.M., F.R.Ae.S., F.I.M., F.R.S.A.

Major Teed, who is Deputy Chief of Aeronautical Research and Development with Vickers-Armstrongs (Aircraft) Limited, was educated at Dulwich College, the Imperial College of Science, Royal School of Mines and the Inns of Court. He served in the R.N.A.S. and the R.A.F. from 1914 to 1922, and has held various technical positions in the Vickers-Armstrongs organisation since 1924. He was the 1953 Simms Gold Medallist.

He is the author of numerous papers on the chemistry and physics of materials, and among his publications are "The Chemistry and Manufacture of Hydrogen", "Duralumin and its Heat Treatment", and "The Properties of Metallic Materials at Low Temperatures".

Major Teed.

NOT only do I regard it as a very great honour to have been invited to lecture to the members of the Institution of Production Engineers, but I also look upon it as a later day miracle. I am not a man of learning and, if there is any field in which my ignorance is greater than another, then it is in that branch of engineering to the development of which your Institution has so successfully devoted its not inconsiderable energies. In this communication, which you will have had an opportunity of reading before we meet, I have attempted to present in broad outline the airframe fatigue problem as I see it. When we do meet, should you give me your permission, I will give an "off the cuff" dissertation indicating, again somewhat broadly, certain matters with regard to which your co-operation can be especially helpful.

An Historical Note

To make an historical approach to my subject — "The Fatigue of Aircraft" — I will now take a very brief backward look both at fatigue and at aircraft.

Firstly, of fatigue : in a period starting prior to the French Revolution and going on into our industrial one, a few observant engineers, and here mention should be made of Albert, Marcoux, Arnoux and Poncelet, established that parts made of ductile metal sometimes broke with a brittle fracture after repeated use, when subjected to loads which they had long withstood with apparent immutability.

Poncelet, pondering on this phenomenon, and he was probably something of an expert on pondering, for he was in a Russian prison from 1812 - 1814, which one might imagine, bearing in mind the date and place, gave ample scope for unheated reasoning,

christened, or better, for so evil a thing should surely not be christened, gave it the name — Fatigue.

McConnell, a British railway engineer, just over a century ago, produced a theory to explain it. This was fundamentally unsound but, illustrating the truth of Mark Anthony's dictum "the evil that men do, lives after them", is not yet dead ; the half-educated as is so often the case, have apparently given it an undeserved immortality.

Then, three-quarters of a century ago, came Wöhler who, with characteristic German thoroughness, established the relationship between repeated stress and endurance at that stress. His results are shown in Fig. 1. Note how markedly reduction in the applied stress increases its fatigue resistance. Lowering the applied range of stress from $\pm$ 15.3 tons/in^2 to 14.3 tons/in^2 increased the endurance of the specimen from 56,000 to almost 100,000 reversals. This is impressive, but if the stress was approximately halved, i.e., reduced from $\pm$ 15.3 to $\pm$ 7.6 tons/in^2, the capacity to withstand repeated stresses was increased more than 2,340 times, for the specimen was *unbroken* after over 132,000,000 reversals. Wöhler did not show his results graphically, so I have done it for him, in Fig. 2. We have seen better S/N curves but, in a sense, this is the first of them all and we have certainly seen worse ones.

To turn now to aircraft, a little over half a century ago, at Kitty Hawk, in North Carolina, on a dull December day, before an apathetic audience of some five persons, Orville Wright flew, at a modest height, at a speed of some 30 miles an hour, for a distance of about half a mile, a "stick and string" machine weighing 750 lb., having a 12 h.p. engine ; the Fatigue of Aircraft had begun, but since in the early days of the new era, the machines had very short lives, its insidious attack passed largely unnoticed, certainly as far as the airframe, then mainly made of wood, was concerned. In the engine, however, crank-shafts and exhaust valve springs, certainly did fail by fatigue in the First World War.

When between the Wars, wood gave way, as a structural material, to alloy steel and later to age-hardening aluminium alloys, fatigue failures occurred in a number of structural components, but they were not, as yet, attributed to fatigue, but to "vibration". Later, to describe similar failures, two new terms :

WOHLER'S TESTS ON AXLE IRON

Specimen No.	Applied Range of Stress. (Tons/in ^{2}).	Number of Repetitions to Fracture.
1	$\pm$ 15.3	56,430
2	$\pm$ 14.3	99,000
3	$\pm$ 13.4	183,145
4	$\pm$ 12.4	479,490
5	$\pm$ 11.5	909,840
6	$\pm$ 10.5	3,632,588
7	$\pm$ 9.6	4,917,992
8	$\pm$ 8.6	19,186,791
9	$\pm$ 7.6	132,250,000 (unbroken)

Fig. 1.

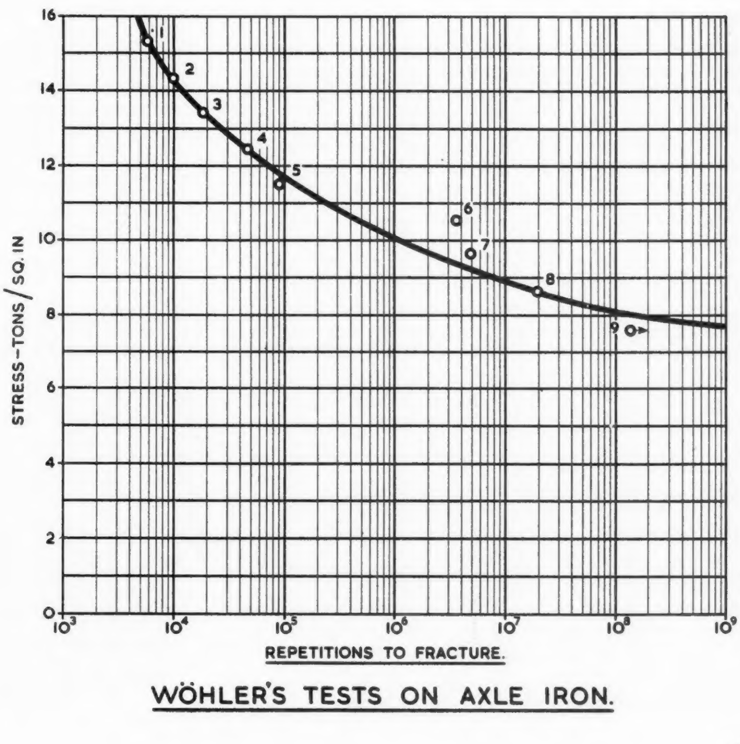


Fig. 2.

WÖHLER'S TESTS ON AXLE IRON.

THE MATERIALS OF WHICH THE AIRFRAMES (EXCLUDING UNDERCARRIAGES) OF TWO LARGE CONTEMPORARY AIRCRAFT ARE BEING MANUFACTURED.

(Basic equipped weight of each about 70,000 lb.).

Material and Form.	Weight as percentage of Total Structure Weight.			
	Aircraft A		Aircraft B	
Aluminium Alloys:-				
Sheet and strip	44.0		58.7	
Bars and sections	28.0		18.3	
Tubes	2.0		1.4	
Castings and forgings	2.0	76.0	2.4	80.8
Ferrous Alloys. All Forms		8.0		17.0
Magnesium Alloys. All Forms		3.0		0.3
Copper Alloys.		1.0		0.7
Miscellaneous Materials All Forms.		12.0		1.2
		100.0		100.0

Fig. 3.

"flutter" and "buffeting" came into being, but in 1931, W. D. Douglas, then of the Royal Aircraft Establishment, Farnborough, and still happily with us, described certain component failures as being due to fatigue, as they most undoubtedly were.

In the Second World War, aircraft, though their lives were normally very short, did, in fact, sometimes fail from structural fatigue and, since then, they have continued so to do.

How comes it that, nearly a century after Sir William Fairbairn had pointed out that structures subjected to repeated loading might well fail at stresses below their elastic limit, airframes have so failed ? The short answer, as is indeed so often the case where human error is concerned, is just human ignorance.

The selling of aeroplanes being an intensely competitive business, the aircraft designer has to do his utmost to attract the potential customer. To succeed, he has to offer a better combination than his rivals of such qualities as disposable load, range, speed and freedom from major fatigue failure. These are largely incompatibles ; like Jason of old, the designer must steer between Scylla and Charybdis, the aircraft equivalents of which are : what has an immediate economic appeal, and *what* is *safe* and *in long term, remains safe*. Aircraft designers, indeed, require the judgment of Solomon, together with a power to resist temptation comparable with that of a mediaeval saint.

TENSILE AND FATIGUE PROPERTIES (ROTARY CANTILEVER TEST) OF WROUGHT ALUMINIUM ALLOYS (ALUMINIUM LABORATORIES LTD.).

Inglis Stress Concentration in Notched Fatigue Test Pieces equals 5.

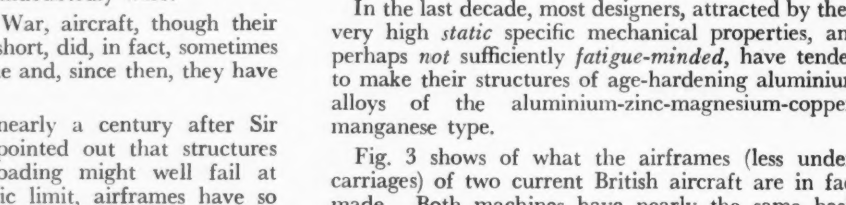
Alloy U.S. Approximate Designation.	Ultimate Tensile Stress, lb/in².	—Endurance Limit— 50 x 10⁶ Cycles lb/in².		Reduction due to Notch. Per Cent.
		Standard	Notched.	
17ST	61,600	±22,200	±9,900	—44.5
24ST	64,300	±22,200	±9,900	—44.5
14ST	71,000	±22,200	±9,600	—44.5
75ST	74,600	±26,700	±9,000	—66.4

Fig. 4.

In the last decade, most designers, attracted by their very high *static* specific mechanical properties, and perhaps *not* sufficiently *fatigue-minded*, have tended to make their structures of age-hardening aluminium alloys of the aluminium-zinc-magnesium-copper-manganese type.

Fig. 3 shows of what the airframes (less undercarriages) of two current British aircraft are in fact made. Both machines have nearly the same basic equipped weight ; it is about 70,000 lb. Neglecting rivets, and at a later stage I shall emphasise why this should not be done, both airframes contain over 65,000 parts. Both craft are predominantly made of

Fig. 5.



wrought aluminium alloys and, *en passant*, one might point out that one machine contains ten times the magnesium alloy of the other ; however, ten times next to nothing is scarcely something ?

Fig. 4 (for the information on which it is based, I am indebted to Aluminium Laboratories Ltd.) gives typical tensile stress, unnotched and notched fatigue figures for forged testpieces made of five different aluminium alloys, all of which were in production in early post Second World War years. The points to note are that while the tensile of 75ST is about 21% higher than that of 17ST, and its yield, not shown on the Figure, is about 73% higher, its notched fatigue endurance for 50×10^6 cycles when the stress concentration is 5, is actually lower than that of all the older alloys under comparable circumstances. This disappointing feature of these stronger light alloys is now well confirmed. In Fig. 5 the outstanding things to note are :- (i) this impressive rise in yield strength and (ii) the insignificant rise in *notch* fatigue-endurance when the Inglis stress concentration was 40 and the stress reversals were 500×10^6. I might add that had the stress concentration been more modest, say, five, I think the same pattern of results would have been obtained. So much, for the time being, for the material side of this question.

I am going to suggest there is something of an analogy between the current incidence of fatigue in aircraft and of cancer in human beings. Numerous short-term causes of aircraft and human disaster have, by hard and intelligent work, been in large measure eliminated, so the long-term ones become increasingly conspicuous.

To ask a rhetorical question — why do fatigue failures occur ? Well ! my reply is because of the repetition of loads which, were they but static, the structure would have withstood indefinitely — *repetition* is the villain of the piece and in the four operations — taxiing, take-off, flight and landing — it turns up with quite devilish ingenuity, sometimes but once in many hours and sometimes more than a million times in a single hour, and a million is a very great number indeed — we are not yet a million days from the start of the present era.

At one end of the scale in a modern aircraft is the fuselage pressurisation stress cycle. With the ponderous inevitability of a State Ceremonial, stress reaches its maximum when the aircraft is at its maximum height. It is zero at ground level and on landing, of course, returns to this figure. Thus, its frequency is generally measured in hours. On the other hand, from the jet gases of a multi-engine machine, the lateral vibrations, which hit the side of the fuselage or the under surface of the wings and/or ailerons, have a frequency of from about 10,000 - 20,000 cycles a minute. Those of a propeller blade may be as high as 27,000 per minute. Impressive as these figures may be, they are, however, as nothing to the fluctuations of the blade of a gas turbine. These may be higher than 200,000 per minute, but as I am

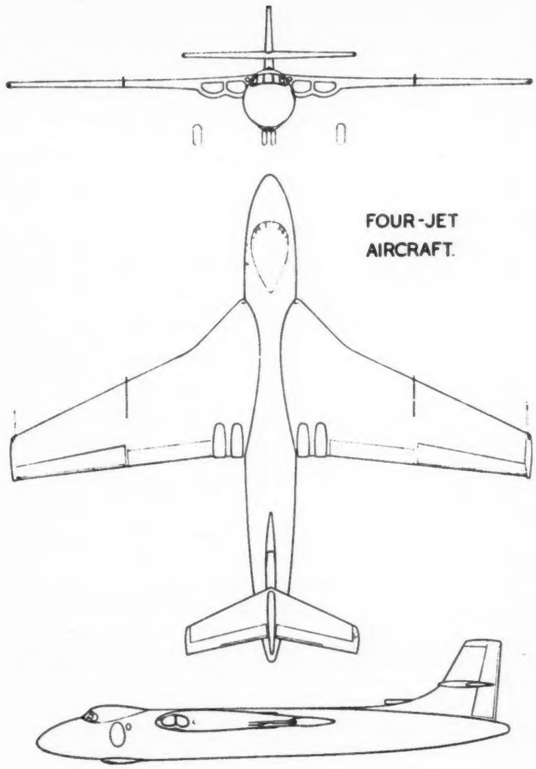


Fig. 6.

dealing primarily with the airframe, I shall make no further reference to it.

Fig. 6 is of a modern four-jet aircraft having a wing span of about 100 feet. When the machine is on the runway waiting to take-off, to use the language of exaggeration, the wings are drooping downwards due to their own weight and that of the fuel in them ; the tail plane is also loaded under its own weight ; the fuselage is stressed as a beam and the wheels are loaded in compression in the plane of their vertical diameters and in tension in that of their horizontal ones. If stress, in a Piezo-like way, gave rise to colour, then the machine would look far gayer than Joseph's most sartorially daring coat, which, I have no doubt, would have given Savile Row an attack of the staggers.

What happens when the aeroplane starts to move ? Amongst other things and, starting with a real glimpse of the obvious, the wheels of the undercarriage begin to rotate — the direction of the stresses remains constant, but the material subjected to them is continually changing. Per revolution, that on any one diameter is subjected to two compressive and to two tension stresses. At the start, these stresses will be high and their frequency low, but, as horizontal speed increases, wing lift develops, so they decrease in magnitude

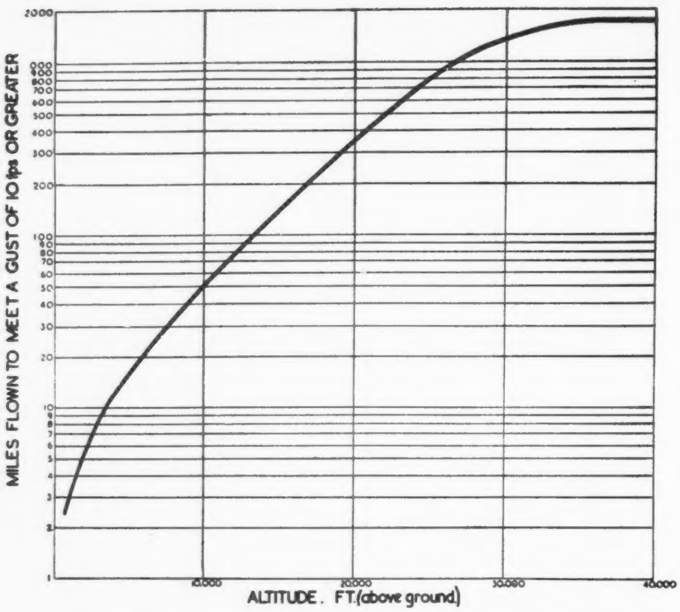


Fig. 7.

VARIATION OF GUST FREQUENCY WITH ALTITUDE.

but increase in frequency, reaching (in the case I have in mind) about 1,800 reversals a minute. So much for the fatigue of wheels during take-off. Due to the inequalities of the surface over which they roll, accelerations or jolts will be transmitted to all parts of the structure.

At the moment the machine begins to move, the upper portion of the wing structure will be in tension, but when airborne, the reverse will, of course, be the case. The jolts arising from the inequalities of the runway, have on several occasions been sufficient to produce such variations in the stresses of the wing structure as to cause fatigue failure in the portion loaded in compression in flight, i.e., the upper side.

For the moment, so much for the repeated stresses arising when the aircraft is moving on the ground. What happens when it becomes airborne ? It is subjected to fatigue producing stresses of five different kinds, which may be *simultaneously* imposed on each other. These stresses may be produced by :-

(i) the use of the controls;

(ii) the vibration of parts at their natural frequency, engendered by passage through the air ;

(iii) the unbalanced forces from the power plant and/or from the jet stream ;

(iv) the pressurisation of the fuselage ;

(v) the turbulence of the air through which the aircraft flies.

I will now refer to merely two categories of stress : those arising from turbulence of the atmosphere and from pressurisation.

In Fig. 7 a most important fact is revealed —*flying high is the best way of avoiding turbulence and, therefore, structural fatigue.* Fig. 7 shows the average frequency of gusts in *Southern England* of 10 feet/second and over from ground level to 40,000 feet. When flying at 5,000 feet, such a gust is encountered about once every 18 miles ; at 10,000 feet, this distance is increased to 50 miles ; at 20,000 feet, it becomes 350 miles ; and at 40,000 feet, it is increased to 1,800 miles. Parenthetically, I would criticise the custom of dealing with this matter in terms of height above sea-level ; scientifically, it would surely be better to use vertical distances above or below the tropopause ?

The foregoing constitutes one very good reason for flying high. Fig. 8 discloses another, wherein the relationship of atmospheric density with height is shown. Since for gusts of equal size and velocity the loads arising from them will be proportional to the density of the air of which they are composed, from the point of view of reducing the fatigue of aircraft structures, there will be an additional advantage in flying high. To take an example, for gusts of equal velocity and of similar form, the load engendered at 40,000 feet will be only one-quarter of what it would be at ground level.

Combining the information contained in the last two Figures allows one to say that at 40,000 feet one experiences only 1.0% of the gusts at 5,000 feet, and that one of these would only impose about 28% of the load to which it would give rise at the lower altitude.

To condense what I have written at too great length into three, perhaps too short, sentences :-

(i) to obtain the longest working life from an aircraft, it should be flown at the greatest practicable height;

(ii) ideally, one should fly above the tropopause;

(iii) since, however, this is at some 25,000 feet above the Poles and over 60,000 feet above the Equator, what is ideal is not invariably attainable.

I have given some striking advantages which can be gained from flying high but, in aviation, as in other fields of human activity, Chalmers's oft misquoted maxim — " What you gain on the swings you lose on the roundabouts " — applies, and applies with a vengeance (incidentally, this misquotation is better than the original, which is very often the case). Flying high necessitates pressurisation of the fuselage, so, superimposed on all the fluctuating stresses engendered by flight, it has to withstand a steady tension one, due to the difference between its internal and external pressure — at 40,000 feet this would be about 8 lb/in². Production engineers may not consider this steady tension load arising from pressurisation as a serious augmentation of the aircraft fatigue problem. However, it undoubtedly is one, for the mean of many of the fluctuating stresses imposed on the fuselage will, as a consequence, be a tension one.

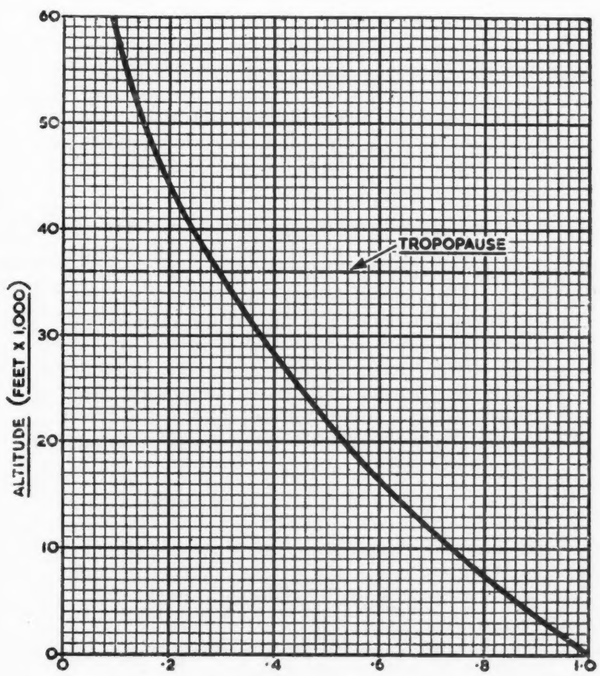
Fig. 9 shows how adverse is the influence of a mean tension stress on one of the current wrought aluminium alloys, much used in aircraft construction. If the mean stress is zero, this alloy has a 10^7 endurance limit of over 20,000 lb./in² ; if the mean stress is 22,400 lb./in², which is well below the elastic limit of the alloy, it falls to about 16,000 lb./in² ; and if the mean stress is 44,800 lb./in², which is well below the 0.1% proof stress of the alloy, the 10^7 endurance limit falls to a mere 5,000 lb./in². I might add that the lack of success obtained some 15 years ago by British propellers made of forged magnesium alloy was, in part, due to the relatively poor fatigue properties of the material when the mean stress was a tensile one ; metals, you know, have very different ways of reacting to a mean cyclic stress which is a tensile one.

Having looked in a very superficial way at some of the flight fatigue problems, let's come down to earth.

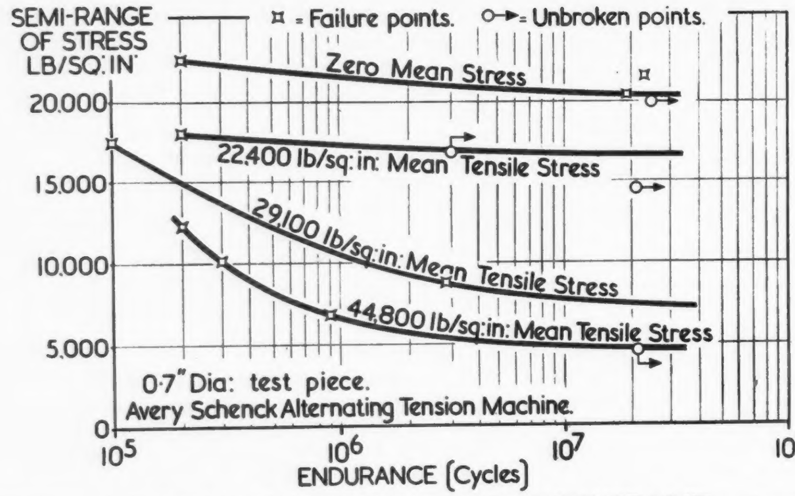
The transition from being wholly airborne to being wholly supported by *terra firma* can be made almost without shock and, therefore, without creating any large and rapid change of loading. I can give accelerometer records proving this, but I also can give evidence to the contrary.

So much for what is generally the touch-down — subsequent repeated loads will be comparable with those which occur during take-off, but their frequency will decrease and their magnitude increase as the speed of the machine decreases. There is, however, one further point which has to be made with regard to landing : at landing, the aircraft possesses very considerable kinetic energy (I am thinking of some

Fig. 8.



The variation of relative density with height.



INFLUENCE OF MEAN STRESS ON ENDURANCE LIMIT OF EXTRUDED D.T.D.364 POLISHED BAR (APPROXIMATELY 14.S.)

Fig. 9.

120,000 lb. moving at 100 m.p.h.). Unless the machine has some reverse thrust device, much of this energy has to be absorbed by the brakes — it is, of course, converted into heat and is eventually largely transferred to the wheels ; thus, as far as the fatigue problem is concerned, that of the wheels is greatest during *taxiing* from the runway to the point of disembarkation — a distance which is frequently measured in miles and often traversed over rough routes — the greatest enemies of civil aviation are the mismanagers of civil airports. The airplane is, of course, a flying machine. This leads those not closely associated with it to overlook the fact that it is a more than somewhat clumsy land vehicle, suggesting to me, in its perambulations, the gracelessness of the most awkward of sea-lions when out of water.

With the most numerous type of civil aircraft, the inter-city machine, the taxiing and take-off running amounts to at least 1% of the distance it covers in the air. This is not perhaps an immediately impressive figure but, since the contemporary inter-city machine is expected, in its working life, to fly for a total of 30,000 hours, at a speed of about 300 miles an hour, its elephantine body has to be pushed along the ground, under a variety of conditions, for about 90,000 miles. This, in terms of land or sea transport, is no inconsiderable distance.

So far, I have written as a ' tabloid historian ' and as a ' pseudo-engineer '. I am now going to give you a brief account about some physical-metallurgical aspects of fatigue and, though their name is legion, I am going to deal with but three of them :-

(a) stress concentrations ;

(b) scatter in fatigue test results ;

(c) influence of built-in stresses.

Stress Concentrations

The vast majority of several thousand papers relating to fatigue support their conclusions on the basis of experimental results derived from *un*notched testpieces. This information is, however, of little value to the engineer ; if it be true that you cannot make a silk purse out of a sow's ear, then an equal measure of veracity must be given to the dictum that you cannot design a mechanism or structure without stress concentrations.

To revert to the two airframes of the structural materials to which I initially referred — both these contain more than a million rivets, each one of which gives rise, not only to more than one stress concentration, but to more than one localised residual but indeterminate stress. Fig. 10 is relevant — it shows the influence of stress concentrations on the fatigue endurance of testpieces made of the wrought aluminium alloy 75S - T6. When the Inglis stress concentration is one — that is to say, the testpiece is *un*notched, the 10^7 endurance is about 14 tons/in^2 ; when it is 3.25, the 10^7 endurance falls to about 8 tons/in^2 ; and when it is 20 or above the 10^7 endurance is about 5 tons/in^2 which is something like one-seventh of the alloy's 0.1% proof stress. I would particularly draw attention to the fatigue resistance when the stress concentration is about three. I do this because A. O. Payne has carried out in Australia a truly remarkable experiment by fatigue testing, not 91 Wöhler or 91 Haigh testpieces, but 91 complete wings of " MUSTANG " aircraft. Amongst others, he draws the very interesting and important conclusion that such a structure has a fatigue endurance comparable with that of a notched testpiece, made of the same alloy having a theoretical stress concentration somewhat greater than three.

There is yet another aspect of this multi-faceted problem — the increase in stress concentration which can arise during the life-time of an aircraft. This may be caused by corrosion, with or without its *sub-variants*, stress corrosion, corrosion fatigue and contact corrosion. Such concentrations may also be brought about by erosion and by abrasion, which last word is intended to include fretting.

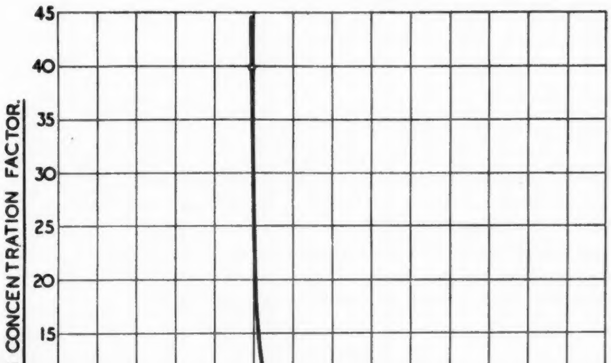
An aeroplane, whether it be at rest or in flight, is ever exposed to corrosive conditions of varying degree of intensity. At ground level or perhaps better, at sea level, it is in contact with moist air, not infrequently containing detectable amounts of salt. Such air, of course, goes throughout the aircraft where, depending, *inter alia*, on the measure of protection provided, it may prove to be an active corrosion agent, giving rise to pits or to inter-crystalline valleys from which, under the influence of repeated stresses, cracks may start.

Within the fuselage of a pressurised aircraft, which normally flies below the tropopause, there are great possibilities of corrosion and, therefore, of stress concentration of a high order. The passengers and crew breathe the air they are so generously given — they get about $1\frac{1}{2}$ lb. per head per minute. Unconcernedly and without any expression of gratitude, they return it to circulation, but in a far worse condition. It is more than shop-soiled. They have added both moisture and carbon dioxide. The former, containing some of the latter in solution, condenses possibly as a pleasing opalescent film on the inner surface of the hull. From here it runs down to become, not a few cubic centimetres, but possibly sloshing gallons of revolting chemically active liquid, capable of promoting one or more types of corrosion. No wonder an American airline executive has said, with his countrymen's aptitude for a phrase, that while most passengers appeared to be persons of good heart, without exception, they all seemed to have bad breath.

Whether an aircraft normally flies above or below the tropopause, there is yet another way in which water may get within the machine and thus, by chemical means, produce that physical abomination, a stress concentration. When flying through rain (which is a low altitude phenomenon) at speeds measured in hundreds of miles an hour, the liquid is strongly penetrant, so some water may be driven into the aircraft. Here it may add to corrosive liquid already there, or, should the interior of the fuselage be dry, as it generally is with a machine normally flying in the stratosphere, then it may initiate corrosion. This statement perhaps requires a word of explanation. Since rain is merely condensed water vapour, it might be thought to be of little consequence from the corrosion point of view. This, however, is not so. Due to absorbing oxides of nitrogen, produced by thunderstorms, or from the vapour condensing on airborne particles containing *water soluble salts*, it, particularly in the tropics, often contains substances capable of promoting corrosion.

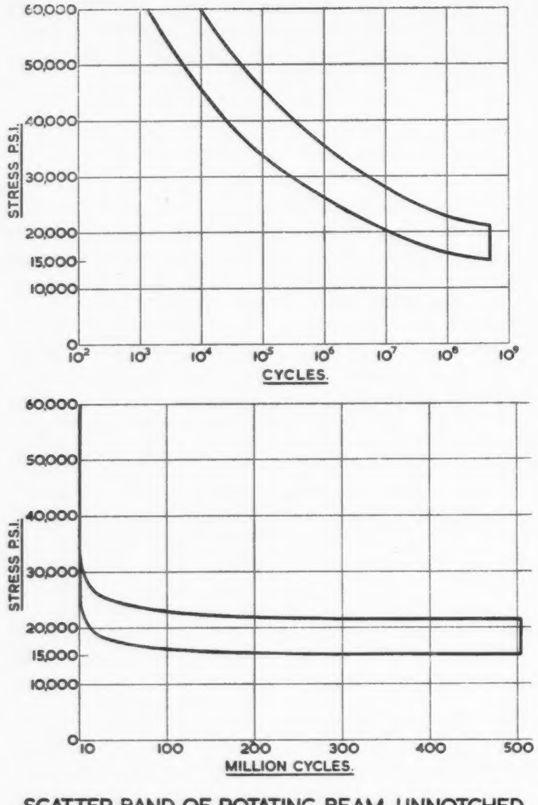
Abrasion produces stress concentrations in propeller blades. This has long been a most serious problem, particularly with military craft, for these

Fig. 10.



INFLUENCE OF STRESS CONCENTRATION ON 10^7 ENDURANCE OF NOTCHED 75S-T6 TESTPIECES

(TEMPLIN)



SCATTER BAND OF ROTATING BEAM. UNNOTCHED FATIGUE TESTPIECES OF 14S-T6.(TEMPLIN).

Fig. 11.

often take-off in formation, when dust, grit and small stones, thrown up from the runway by one machine, strike the propeller, the rotational tip speed of which may be as high at 600 m.p.h., of a following one. Further, since both in airframe and engine there are many close fits and there is also vibration, fretting, which, of course, produces stress concentrations, occurs unless very special precautions are taken.

Scatter

It will be known to those who work or have worked in test-houses or research laboratories that as far as the *static* properties of alloy or of wrought aluminium alloys are concerned, the variation in the same batch is generally small, say, 3 - 5%. With the fatigue endurance of these and of other metallic materials, this variation or scatter is vastly different. Fig. 11 shows this in relation to unnotched rotating beam-testpieces of the wrought aluminium alloy 14S - T6, and the experimental results are plotted in two ways. In both graphs the stress scale is linear but, in the upper one, the endurance scale is logarithmic and, in the lower one, it is linear. Both tell the same story but perhaps with varying degrees of lucidity ; some have difficulty in appreciating log plotting, but it is quite untrue to say that this is because they have wooden heads. Anyway, when the maximum stress was $\pm$ 50,000 lb./in^2, the ratio of maximum to minimum endurance was *7.8 to 1*, and when the maximum of the repeated stress was reduced to $\pm$ 21,000 lb./in^2, the ratio was *48 to 1* — many further examples of this tremendous scatter at low stresses could be cited.

This large range in results obtained at low stresses may suggest that testing a few identical aircraft structures is of litle value — this is really not so. N.A.C.A., Australian and other experiments have shown that realistic testing of aircraft structures does

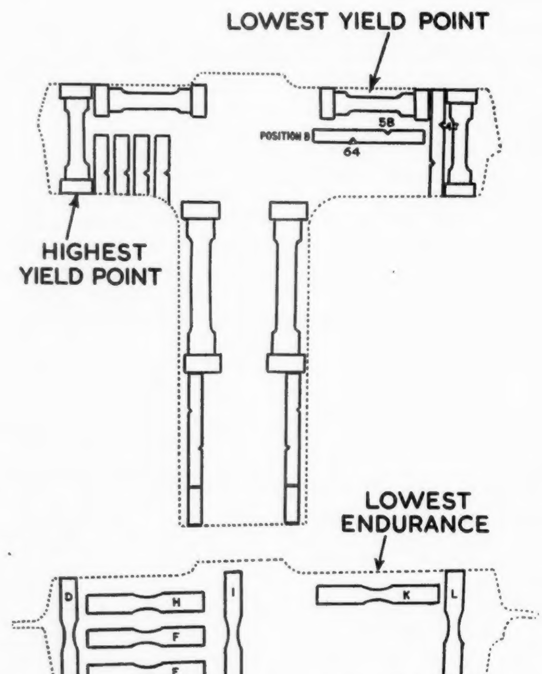


Fig. 12.

not give very great scatter in results ; this is because such testing, due to the millions of stress concentrations, gives rise to relatively high stresses.

The admitted scatter obtained when subjecting aluminium alloys to repeated stress to which I have drawn your attention, may make some who still look upon aluminium as "electrified dirt", suspect that steel would give more consistent results — I doubt this. I now wish to draw your attention to some very interesting experimental results for which I am indebted to my friend, H. H. Burton, of The English Steel Corporation. The experiment involved dividing on one of the planes of symmetry a portion of a forged heat-treated alloy steel crankshaft, as will be seen in Fig. 12. From one of the halves, tensile and impact testpieces, located as shown in the Figure, were cut out and tested. From the other, fatigue testpieces were taken as indicated. On testing the tensile testpieces, the difference in yield point between the lowest and highest was approximately 10% ; the location of these testpieces is also shown in Fig. 12. Turning now to fatigue testpieces, these were subjected to a cyclic torsion stress approximately 0.4 tons/in² above the fatigue limit of this steel when tested in this way. The relative positions of the most and least fatigue resistant testpieces are indicated. They are similar to the tensile ones. Their test results are, however, most impressive — the specimen at location 'K', broke after less than 400,000 stress cycles of the magnitude indicated — that at 'D' was unbroken after almost 15,000,000 cycles of the same stress.

THE INFLUENCE OF HEAT TREATMENT IN RELATION TO THE SEQUENCE OF MANUFACTURING OPERATIONS ON NOTCHED SPECIMENS FROM A LIGHT ALLOY FORGING.

(Annular Notch, depth 0.04 in., included angle 45° and root radius 0.01 in.).

Method of Manufacture of Notched Specimens.	Fatigue-Endurance Tons/in² after 50 x 10⁶ Cycles D.T.D. 150. (naturally aged)
(1) Wholly machined (including notch) from fully heat-treated forging.	± 4.4
(2) Machined to diameter from fully heat-treated forging **re-heat treated** and then **NOTCHED.**	± 7.1
(3) **Wholly** machined (including notch) from fully heat-treated forging and **THEN RE-HEAT TREATED.**	± 7.8

Fig. 13.

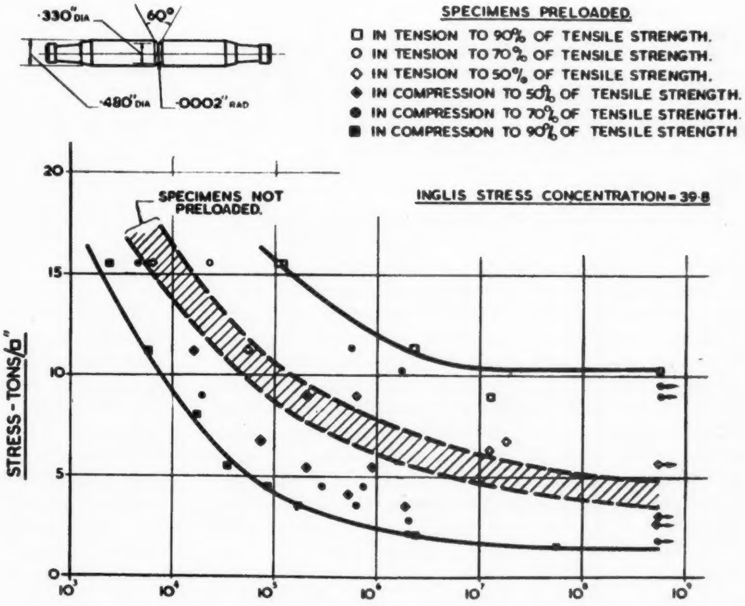


Fig. 14.

Effects of Internal Strain on the Rotating-Beam Fatigue Strength of 75S-T6. (Templin).

EFFECT OF PLASTIC DEFORMATION IN TENSION ON THE FATIGUE RESISTANCE OF ROTATING CANTILEVER SPECIMENS MADE FROM SOME FULLY HEAT TREATED, PLASTICLY DEFORMED, I INCH DIAMETER, WROUGHT ALUMINIUM ALLOY RODS.

Alloy.	Degree of Overstrain	Endurance Limit at 50 x 10^6 Cycles
B.S. 6L1	0	$\pm$ 12.0 tons/in^2
	3	$\pm$ 12.0 „ „
	6	$\pm$ 11.5 „ „
	9	$\pm$ 10.5 „ „
	12	$\pm$ 9.5 „ „
D.T.D. 363A	0	$\pm$ 13.5 „ „
	4	$\pm$ 11.5 „ „
	10	$\pm$ 11.0 „ „
D.T.D. 364	0	$\pm$ 11.75 „ „
	2	$\pm$ 11.75 „ „
	4	$\pm$ 10.25 „ „
	6	$\pm$ 9.75 „ „

Fig. 15.

To summarise — the significance of Templin's (Fig. 11) and Burton's (Fig. 12) quite comprehensive experiments is this :-

(a) variation in resistance to repeated stresses of identical specimens from the same batch or even piece of material is high in comparison with that in the material's static mechanical properties ;

(b) the variation in resistance to repeated stresses is greatest when the magnitude of the repeated stresses is low as compared with the material's static ultimate stress.

Built-in Stresses

I can but briefly draw your attention to what is a very large subject — built-in stresses. These can arise by accident or design and, depending on their nature in relation to the working stresses put upon a part containing them, may either increase or reduce its fatigue resistance. Fig. 13 shows the endurance of test pieces made from a fully heat treated alloy which would be very largely free from residual stresses; those heat treated after machining would have surface compressive stresses but, due to the subsequent cutting of the notch, these would be partly relieved ; and finally, those heat treated after all machining, including the cutting of the notch, would have the highest surface compressive stresses and, as will be seen, the highest fatigue resistance. Though doubtful as to whether metals are mentally bright, they can do some simple arithmetic and so react, in a befitting manner, to the algebraic sum of the stresses imposed on them.

Fig. 14 shows the influence of residual stresses induced by plastic deformation on the fatigue resistance of notched wrought aluminium alloy test-pieces — the beneficial influence of residual compressive stresses is clearly shown. The notched test-pieces having been pre-loaded in tension will contain residual compressive stresses at the base of the notch; this, of course, increases its fatigue resistance. On the other hand, if pre-loaded in compression, the residual stress in the critical area is a tension one.

A further experiment, showing the benefit which can be obtained by the application of loads giving rise to residual compressive stresses, should be mentioned. Heywood of the Royal Aircraft Establishment, testing identical wrought aluminium alloy parts, under a nominal fatigue stress of 7.1 $\pm$ 2.7 tons/in^2, found that the application of a single overload of 17.7 tons/in^2, a stress well above the original elastic limit of the alloy, once every 20,000 cycles increased the fatigue life of the part from about 80,000-770,000 cycles or almost tenfold.

Before I leave this question of residual stresses induced by initial plastic deformation, let me emphasise that its beneficient influence generally only operates when there are stress concentrations, and Fig. 15 shows this. The term 'overstrain' here means permanent stretch, and stretch in excess of 3% appears to reduce the fatigue resistance of the three well known wrought aluminium alloys L.1, D.T.D. 363 and 364.

So much for an all-too-wandering and, in parts, too condensed a tale; in early days, fatigue was not recognised as an aircraft problem—today and long before today, it has been so recognised. It has not been eliminated, but it is becoming increasingly less dangerous because it is becoming increasingly understood.

In 1955 (only a little over half a century since the first aircraft powered flight) some *69,000,000* passengers were carried by the civil air lines of the world, an average length of journey of 559 miles. With sincere regret, it has to be admitted that, of this vast company, *408* lost their lives, and some of these fatalities must be attributed to fatigue. To use President Lincoln's immortal phrase : "We must highly resolve that these dead shall not have died in vain."

REPORT AND DISCUSSION

Chairman: Professor E. J. RICHARDS, M.A.

The **Chairman:** First, I would like to take this opportunity, on behalf of the University, to welcome you here. We like to see you coming here each year. We are now probably the largest aeronautical school in the country, and we like to see aeronautical people in the area.

Secondly, it is with great pleasure that I welcome Major Teed. The theme of the Conference is "New Materials — New Methods", and whenever you mention the words "new materials", you automatically think of Major Teed. He is an authority on topics relating not only to light alloys, but to alloys of other categories and at the extreme conditions of high and low temperatures. Apart from that, he is a person who can discourse sensibly and simply about the most complicated things.

When you talk about new materials, the biggest problem of all, probably, will be vibrations and thermal stresses, and so the topic chosen for this afternoon, relating to the fatigue of materials, is of very considerable interest to all.

Major Teed trained as an engineer at Imperial College and the Royal School of Mines, and also trained as a barrister. So not only can he get into trouble, but he can get out of it. Indeed, having lunched with him for some six years at Vickers, I can assure you that he is a real wizard at getting out of it! I welcome Major Teed on such a very important topic as the "Fatigue of Aircraft".

In introducing his previously circulated Paper (which appears on pages 154 - 164), Major P. L. Teed both emphasised and amplified its main points. While admitting the reality of the aircraft fatigue problem, he contended that it could only be solved by effective collaboration between aircraft designers, maintenance engineers, airline operators, pilots and last, but certainly not least in his estimation, production engineers.

In aircraft design, Major Teed commended the "fail safe" hypothesis, where this was applicable. Where it was not (and he gave a helicopter blade as an example), the design should be based on obtaining a long fatigue life, even though this would involve an increase in weight. To maintenance engineers, he appealed for rigorous and regular inspection. To airline operators he emphasised the great importance, from the fatigue point of view, of flying high and of operating from the smoothest possible runways.

On pilots he impressed the desirability of the slowest rate of manoeuvre compatible with navigational safety. Further, Major Teed called for slow descents from high altitudes. Coming down fast, he contended, was comparable with driving a car at speed along a road of ever increasing bumpiness.

Turning to the part to be played by the production engineer, which he contended was a most important one, Major Teed indulged in a Euclidean dictum:-

> "Components made in conformity to the *same* drawings from material to the *same* specification and even from the *same* sheet or bar, do not necessarily have the *same* capacity to withstand the *same* number of repeated stresses of the *same* magnitude."

The remainder of the speaker's introduction was devoted to examining in some detail the causes contributing to the above perplexity. In particular, he gave marked attention to the great significance of such seemingly simple but actually very complex matters as surface finish, residual stresses, grain size and the presence of inclusions.

Mr. R. E. Mills, M.I.Prod.E., A.F.R.Ae.S. (*Specialist Designer (Mechanical), A. V. Roe & Co. Ltd.*): In your Paper, you have mentioned surface finish in the form of highly polished, not so highly polished, less highly finished, and so on. I appreciate the limitations of the British Standard method, but in view of the obvious far-reaching effects of finish, I should like to know whether you have a more scientific method of determining surface finish that we should be able to use as a yardstick.

Major Teed: I am very grateful for that question. The answer is "No". At present the position is unsatisfactory — further, I ought now to say something that I cut out of my introductory remarks because time was getting on. There is one perplexing thing about surface finishes. The best, from the point of view of smoothness is, I suppose, that obtained by electrolytic polishing. It does not, however, give you the best surface for resisting fatigue. With this queer exception, the smoother the surface from the British Standards aspect, the better it is for fatigue resistance. Electro-polishing, *per se*, does not give the best surface for this purpose.

Mr. R. G. Wilkinson, B.Sc. (*Development Manager, Magnesium Elektron Ltd.*): The old racing motorist used to polish his front axle until it shone in the sunlight on the track. This is said at times to have shown him that fatigue cracks were developing. I think it far more likely that, as a result of bitter experience, he found, perhaps by chance, that if he polished his front axle with loving care the fatigue cracks would be later in developing.

Major Teed: That is very true indeed. Polishing would have a very good effect. It would remove some of the surface stress concentrations which were there. Further, all mechanical polishing seems to leave residual compressive stresses, so such polishing, if directionally well conceived, tends to reduce the

applied tension stresses and thus to increase endurance.

Mr. J. Gregson (*Development Engineer, The Fairey Aviation Co. Ltd., Stockport*): With regard to the machining of forgings and the effect on fatigue strength of later heat treatment, Major Teed raised the question of what stage in the machining process heat treatment should be carried out. If prior to machining, you have a high degree of internal stress, and if after machining, distortion takes place which gives rise to pre-stressing on being built into the airframe. It does not seem fair that either of these problems should be the sole prerogative of the production engineer. Is it not the heat treatment process itself that is at fault, and should not more effort be made to improve this process ?

Major Teed : I have known great benefit derived from heat treating after final machining of symmetrical parts, particularly parts having one very long dimension with a small transverse one. If you plunge such a part with its long dimension at right angles to the surface of the quenching medium, you get no distortion, but, this is important, you get surface compressive stresses. If you plunge the part horizontally into the quenching medium, it goes banana-wise, and you either scrap it or rectify it and, if you adopt the latter course, you put in quite unknown residual stresses. I have known a large number of parts which have been heat treated in the machined state and have thus derived a great increase in fatigue resistance. The result depends on the shape of the part, and whether you exercise that uncommon quality, commonsense, with regard to the quench.

Mr. Gregson : Would you care to say anything about the effect of hot water quenching on forgings ?

Major Teed : You have to use hot water quenching with some massive forgings. During the transition of such forgings from the plastic to the wholly elastic state, you must try to eliminate getting such high internal tensile stresses as to produce discontinuities or cracks. That is one of the things which is of paramount importance.

Mr. J. C. King (*Assistant Chief Engineer (Development), The English Electric Company Limited, Aircraft Division, Warton*): I should like to ask a question and also mention a quite exceptional built-in stress which we found during the past year, as this is an opportunity to describe the stress to a distinguished gathering who will, I hope, pass on the information.

A fitting, Fig. 1(a), containing several bolt holes, failed due not to fatigue, but to stress corrosion caused by built-in stress. On other aircraft it might have led to fatigue failure. It might be said at first sight that the mating part did not fit correctly at 'X' (Fig. 1(a)) and gave rise to a tensile stress in the direction 'L', but that was not so. If that had been the case, one would have caused a crack running across the cleat, but the cracks occurred running between the holes on the inside face. (See Fig. 1(b).) The grain was in the direction indicated and hence our cracks ran along the grain, indicating a cross-grain stress which is known to give rise to stress corrosion failures. Eventually, we found that it was due to a bolting-up stress which was measured by putting two perfectly fitting pieces of metal in the gap as illustrated in Fig. 1(c). We inserted a $\frac{1}{2}''$ strain gauge, and with a reasonable torque amounting to only about 75% of the ultimate failing torque of the bolt, we measured a stress of about 20,000 lb./sq. in. This was a mean stress over the area of the strain gauge and not the maximum stress in the metal, which would be the peak stress causing the failure. This stress was solely due to the local tightening effect and not due to any true bending of the legs of the fitting.

You will appreciate that there are numerous places in aircraft where fittings of this type are used and on many of these you can, no doubt, get high stresses due to local distortion of the fitting as it beds into the material underneath. Our tests showed that these local stresses can be very high indeed.

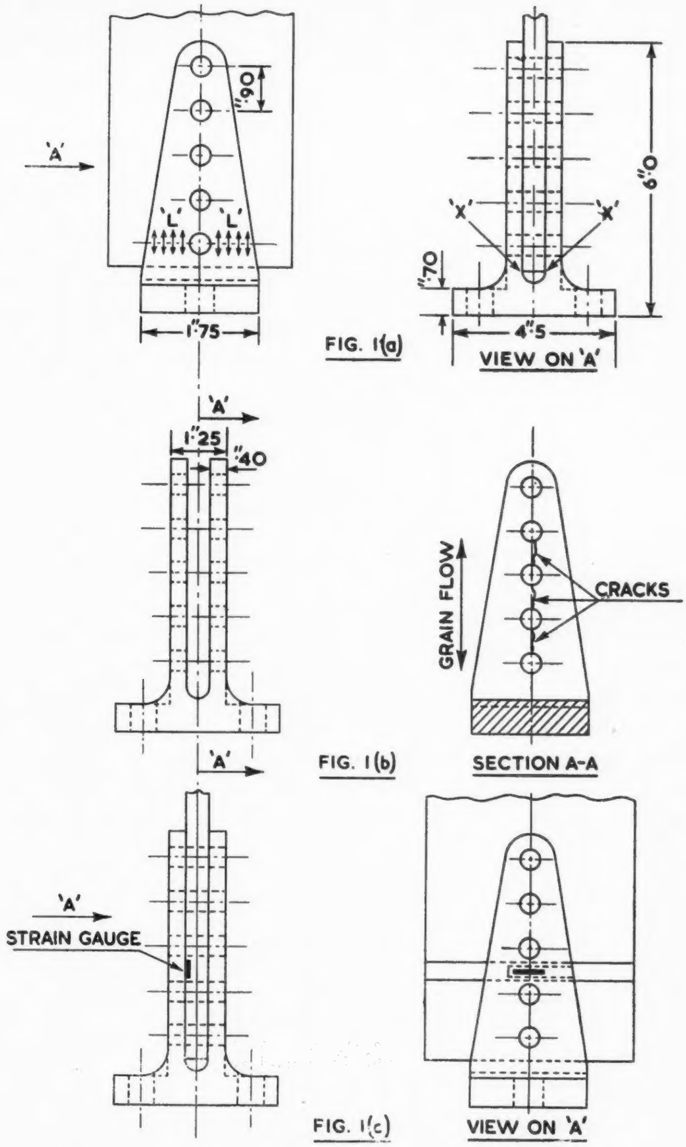
The question that I wish to put to Major Teed is this. Will you be so good as to tell us how, in your firm, you deal with the specification of all these special processes needed for quality control ? Do you put all your drawings through a specification or quality control section ? Is that under design or the works ? Or do you train your planning engineers to know all about fatigue, surface condition and quenching, or do you leave it to your draughtsmen ?

Major Teed : I am not very certain of the answer, but I think it comes from what should be called your technical office. They cannot review every case, but difficult ones must be referred to it. This office then specifies a method of assembly to reduce dangerous residual stresses. I think, however, that very often the technical office only comes in after there has been a failure, for surely it is true of all of us that we learn more from experience than from forethought ?

Mr. F. C. Bartlett (*Production Director, Heathway Engineering Co. Ltd.*): Last year I suggested that industry should standardise its tooling, and made a suggestion about a general method of layouts.

It would appear from what we have heard that there is great importance to be attached to surface finishing and, by and large, it is confined almost entirely to the aircraft industry. Would it not be a good idea for the industry itself to make sure that it has the equipment necessary not only for making the surface finish, but also for measuring it ? The answer given to Mr. Mills gave me the impression that at the present moment that does not exist.

Major Teed : I entirely agree. In the best of all possible worlds, in which I scarcely think we are at present living, we could do much better than we are doing. The British Standards Institution is making slow progress in improving the definition of the technique that can be used. We have got to do research and let the Institution know the results. It



Figs. 1(a), (b) and (c), referred to by Mr. J. C. King *(see facing page).*

is a slow build-up, but it is well worth the effort — *laissez faire* may be politically justifiable but, in the technical field, it is invariably disastrous.

Mr. L. G. Burnard, M.I.Prod.E., A.F.R.Ae.S. (*Chief Development Engineer, Vickers-Armstrongs* (*Aircraft*) *Ltd.*): Would Major Teed give us a short dissertation on the value of the various methods of producing an adequate surface finish ? There are many methods open to us. We can use a polishing bob, ordinary emery cloth, barrel finishing or vapour blasting. Vapour blasting seems to give an apparently worse finish than some of the other techniques, but at the same time it may, and often does, give a better fatigue value. I should like Major Teed to give us some of his ideas on these methods of producing surface finish. I wonder whether he could tell us whether, when a metal fails, it fails through the crystal or around the crystal boundary. That is, is the crystal itself weaker than the bond between the crystals ?

Major Teed : We have two 64-dollar questions here. One I will not attempt to answer — how to produce the best surface finish ? In November, 1952, the Institute of Metals had a symposium on the influence of surface finish. This is a very good publication and is really worth reading. I cannot

give you a synopsis of it in two or three sentences, but I do tell you that much can be learnt from it.

With vapour peening, you destroy the benefit of the surface to some extent, but there is a countervailing compensation — you put in surface compressive stresses. Thus, you reduce the significance of the subsequently applied tensile ones.

With regard to the manner of failure of the metal, it depends what its temperature is in relation to its melting point. If a metal is near to this, it generally fails through the inter-crystalline boundary. If, on the other hand, it is a very considerable number of degrees below its melting point, it fails across the crystal. But there are one or two metals which structural engineers do not use, such as lead and bismuth, which are exceptional. These do not fail through their crystals but through their inter-crystalline boundaries. If there is a corrosive atmosphere, then conditions with the engineering metals are markedly altered. Corrosion may produce a stress concentration by leaching out the inter-crystalline boundary. There is thus an inducement for the metal to fail where it would not normally fail, had no chemical action taken place. This sort of thing sometimes happens in the case of the aluminium-zinc-magnesium-manganese-copper alloys, and with many others.

Mr. L. J. Bolton (*Production Superintendent (Hydraulics), Sperry Gyroscope Co. Ltd.*): Would Major Teed tell us whether he has any experience of the cyclic deep freezing of steels from the point of view of increasing the fatigue strength ? I believe that the Americans have done a lot with this treatment, and I understand that they have had success in increasing the fatigue strength in the case of the higher grade steels.

Major Teed : I have had no practical experience, but I have read a certain amount about it. I understand that if you take some ferritic alloy steels, which have retained austenite, down to a very low temperature and keep them there for some time, when they come back to room temperature, they generally have an increased fatigue resistance, due to an austenitic-martensitic change. At low temperatures, heat-treated ferritic steels always have much improved fatigue resistance and this is, to some extent, not wholly lost on coming back to room temperature if there has been a gamma-alpha transformation.

Mr. W. S. Hollis, B.Sc.(Eng.), A.F.R.Ae.S., M.I.Prod.E. (*Assistant Director, Aircraft Production, Ministry of Supply*): Referring to the Templin diagram, Major Teed showed that a considerable plastic strain, tensile compressive, would increase or decrease the cyclic life. If extensive plastic strains persist, we know by the constant volume principle that these strains, increasing or decreasing the diameter at the notch, will alter the principal stresses in the area. In the case of considerable compressive stresses involving considerable compressive deformation in the plastic stage, followed by a reversal of the stress, the resulting plastic deformation continues rapidly and the ultimate tensile loads drop off. Is there an analogy between the elastic strains that are applied in the frequency tests and the plastic compressive or tensile strains which are applied previously ?

Major Teed : I do not think I know the answer to that question. If your applied stresses are really elastic, then the effect is surely merely the sum of the residual stress and the instantaneously applied stress. But if the applied stress produces further plastic deformation, heaven knows what the answer is.

There is this remarkable fact, that if you put a high initial upward load on the wing of a bomber or transport plane — well over 75% of its failing load — its fatigue life, under flying conditions, is always increased. You have produced a certain amount of plastic flow, and thereby reduced to some extent the significance of high stress concentrations and some residual stresses.

Mr. Hollis : In conjunction with a number of aircraft firms, we are doing a series of cyclic tests of titanium bolts, and the stress range selected is tensile. We want further to this to introduce a rapid method of production examination of materials prior to manufacture, that is, examination of titanium stock from the fatigue aspect before we start on manufacture generally. We have been examining in a preliminary sense ultrasonic fatigue testing. Ultrasonic testing will take us into the heat range, and that will require cooling of the specimens. The nature of induced vibrations will give zero mean stress. Do you think there is any real significance in testing components, or the material from which components will be made, under nearly the same conditions as those to which they would be subjected during their life, or will the simple reversal of stress be sufficient to give a general estimation of the material itself ?

Major Teed : I should think the latter will probably be good enough.

The **Chairman :** I know full well that the discussion could go on for a very long time, but I am afraid that I must now bring it to an end.

On your behalf and on my own behalf, I should like to thank Major Teed for his Paper. He very wisely confined himself to certain aspects of the fatigue of metals. We ourselves are very much involved in the case where you have not a nice simple fluctuating load but a random set of loadings coming on, and there the whole problem of accumulation and accumulated damage laws is very difficult to ascertain, but it looks very much as if the whole of the aircraft, in the case of supersonic aircraft, will be subject to possibilities of fatigue in the future. You are, along the boundary layer, shaking the aircraft along its whole length, and the jet is doing the same. We might well at some later meeting of this Institution go on to that theme, and also we might well have Major Teed here to do a repeat performance, as all good artists are expected to do.

The vote of thanks was carried by acclamation.

NUMERICAL CONTROL OF MACHINE TOOLS IN AIRCRAFT MANUFACTURE

by O. S. PUCKLE, M.B.E., M.I.E.E.

Mr. Puckle.

Mr. Puckle, who is Chief Lecturer with E.M.I. Electronics, Ltd., has done research work on radio, television and radar. He translated a book, "Television Reception", from the German and wrote "Time Bases", which has been printed eight times and translated into French, Dutch and Russian.

He has served as a member of the Radio Section Committee of the Institution of Electrical Engineers and has been awarded its Duddell Medal, and has shared its Radio Medal with Mr. L. H. Bedford. He has also served as Secretary and, later, Chairman, of the Television Society.

THE Paper opens with an historical description of the application of numerical control to machine tools followed by a definitive explanation of the term, an account of the various machines available and the work already done with their aid. The types of work for which numerically controlled machines are now in course of development is next discussed, together with a brief description of a numerically controlled skin miller. This is followed by some opinions as to the advantages to be gained by the use of numerical control.

The Paper ends with appendices on the types of machine tool control, the EMI analogue system, some of the mechanical problems of machine tool design and the problems of programming.

HISTORY

Much work was done, during the War, on the servo positional control of guns and searchlights by signals received from radar systems, and it was inevitable that engineers and physicists should search for means of applying the new techniques developed for these purposes to the arts of peace. Unfortunately, it is a fact that there is still a need for using these techniques to further the arts of war. One result of these endeavours, which is, as yet, only in its infancy, but likely to assume tremendous importance in the future, is the electronic numerical control of machine tools.

The first system to be demonstrated was developed by the Massachusetts Institute of Technology. The control system was applied to a Cincinnati "Hydrotel" milling machine and was put into operation in 1952. The equipment served to show the possibilities of machine tool control but it was rather slow in operation and it took too long to prepare it for action.

Since the M.I.T. system was produced other systems have been developed and made by EMI Electronics Ltd.; Giddings and Lewis Machine Tool Company (Numericord); Cincinnati Milling Machine Company; Ferranti Ltd.; Bendix Aviation Corporation; North American Aviation Corporation (Numill); and Electronic Control Systems Inc.; while static positioning systems have been made by B.T.H.; General Electric Co. (U.S.A.); Pratt and Whitney; and Arter Grinding Machine Company (Jigomatic); and "record and play-back" systems have been made by General Electric Co. (U.S.A.); and Hewittic Co. (Paris).

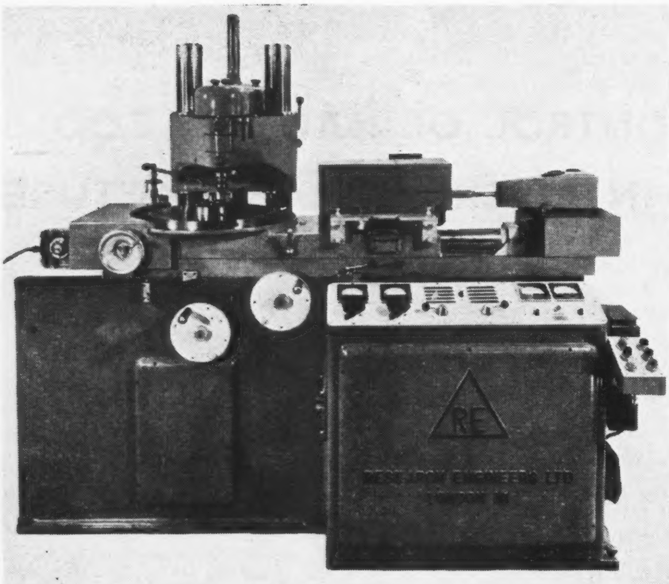


Fig. 1. Modified Research Engineers Cam copying machine, fitted with numerical control.

The "record and play-back" system was a very early method of controlling a machine tool. A first-class machine operator cut the part to be made by manual control of the machine and the motions of the slides were recorded on magnetic tape. By "playing-back" the tape, and feeding the resultant signals to servo motors, the original manually controlled motions were repeated.

There have, naturally, been considerable differences between these various systems and it would serve little purpose to describe them in detail. Instead, the system with which my Company has been associated will be used as an example to illustrate the possibilities and advantages of numerical control. The system is, of course, applicable to many types of machine and to many purposes.

NUMERICAL CONTROL

There are many forms of machine tool control. Many machine tools have been made to operate automatically when once set up; these include, for example, automatic lathes and tracing or copying machines. We now have a new system of machine tool control, known as numerical control, in which the machine is given instructions in the form of numbers for the motion of the slides and the cutting head and it is this information which, when presented to the machine, causes servo motors, or servo valves, to determine precisely the motions of the various parts of the machine. The term "numerical control", which was coined by the Massachusetts Institute of Technology, means simply that the motions of the machine are controlled by the injection of numerical position information.

This is a vast step forward in the control of machines which will permit more complicated parts to be made more quickly, more accurately and more cheaply. It provides a quite fantastic advantage which we cannot possibly afford to ignore.

VARIOUS MACHINES AND WORK DONE WITH THEIR AID

Numerical control was first applied by my Company to vertical milling machines, including two-dimensional, rotating table, cam millers and two- and three-dimensional millers of conventional type with leadscrew or hydraulic drive.

Fig. 1 shows a Research Engineers Cam copying machine, modified by the addition of numerical analogue control equipment. This machine has a slowly rotating worktable which is moved sideways with respect to the cutter according to the numerical instructions so that a cam or similar part may be made, usually with a single rotation of the worktable.

Fig. 2 shows a Cincinnati No. 3 dial type miller fitted with control equipment for two-dimensional operation. The vertical axis is not controlled.

Fig. 3 shows a Wadkin Router similarly fitted. This has been called a two-and-a-half-dimensional miller because the vertical axis control is not continuous. The height of the head is controlled in such a way that it may be moved to any of three vertical positions. Each of these may be positionally preset by the adjustment of stops which operate microswitches.

Fig. 4 shows a Cincinnati sixteen-inch "Hydrotel" miller fitted with control equipment. Since, in this machine, the slides are hydraulically driven, the servo-motors are replaced by hydraulic servo-valves and cylinders.

The work done with the Research Engineers Cam copying machine includes all sorts of flat cams of

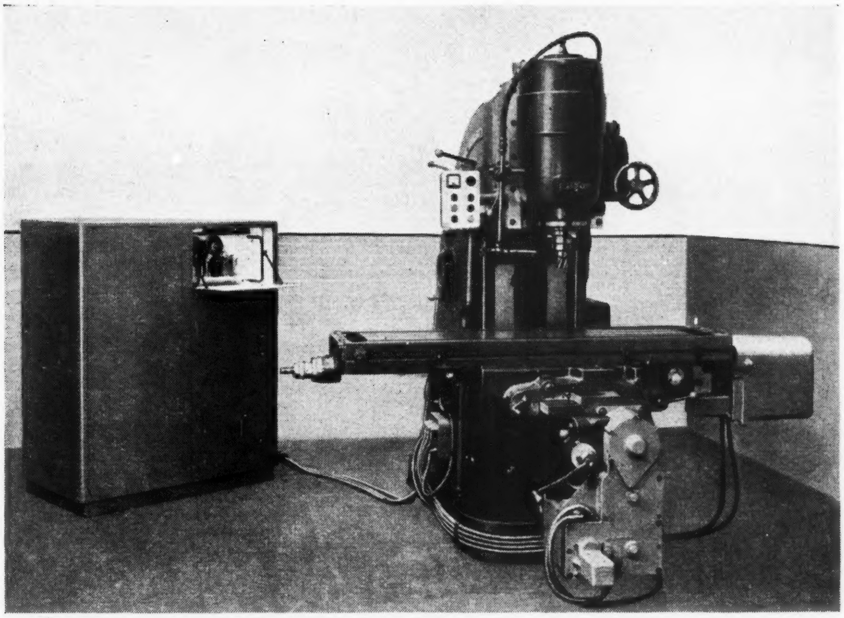


Fig. 2. Cincinnati No. 3 Dial Type Miller fitted with numerical control.

which an example, shown in Fig. 5, was cut in 45 minutes, including a finishing cut, with an accuracy of .0009", the time required for making the tape being half-an-hour. The maximum diameter of the cam is $10\frac{1}{4}$" and it is made of $\frac{3}{32}$" stainless steel. The manual manufacture of the cam would take three weeks. This machine has now been in use at the Laurence Scott factory at Norwich for many months.

The Cincinnati No. 3 machines have been used for cutting many parts of varied shape, an example of which is shown in Fig. 6. This is a lathe template and is typical of the work done by one particular customer. The templates are made of $\frac{1}{8}$" gauge plate and are within $\pm$ .003" of the expected dimensions. with a repetition consistency of $\pm$ .001". The machine can do work up to 27" $\times$ 13". The cutting time for a piece of this type might be 15 to 90 minutes,

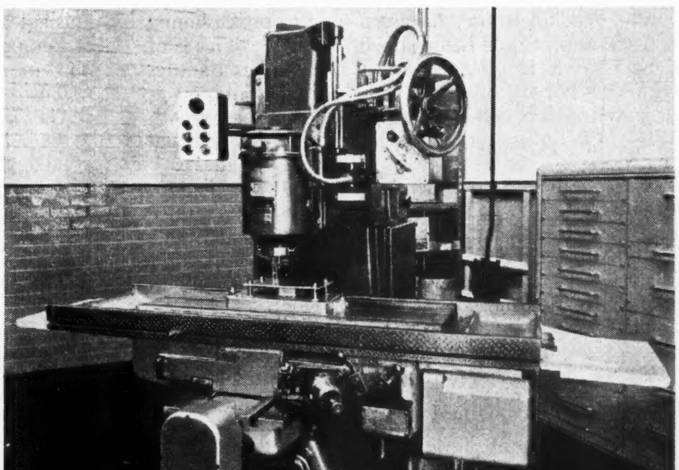


Fig. 3. Wadkin Router fitted with numerical control.

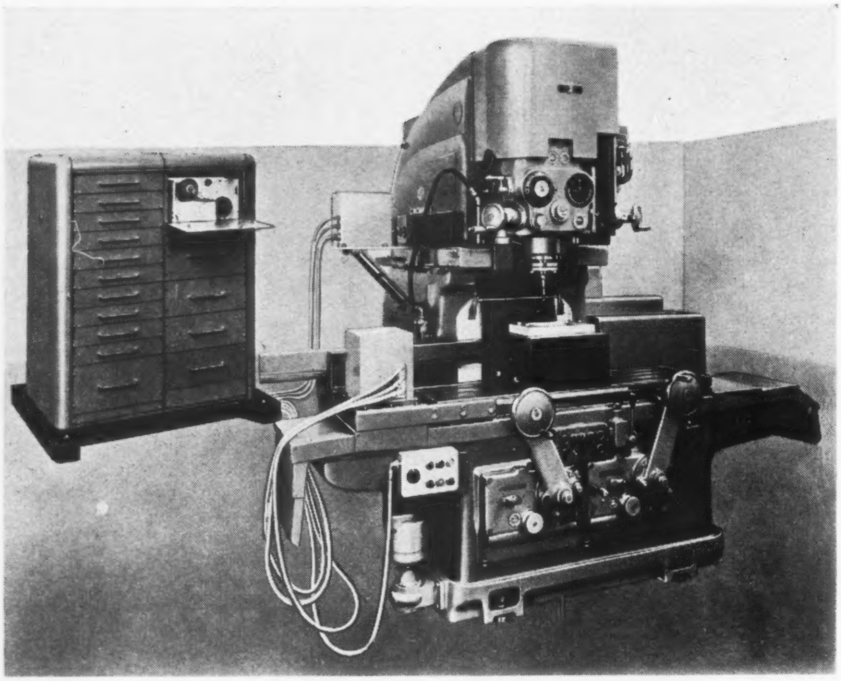


Fig. 4. Cincinnati 16" "Hydrotel" Miller fitted with numerical control.

depending on the cutter and the material, and the basic programming time would be about an hour and a half, including the reduction of the original drawing to a manageable form. Much more programming time might be spent to get the best out of the system. It is expected that it would require 15 hours to make this part manually.

The Wadkin Router has been used to profile many articles, an example being shown in Fig. 7. This is of light alloy, $\frac{3}{8}$" in thickness and it is cut in six minutes with an accuracy of $\pm$ .005", and the programme was prepared in four hours. This may be compared with 12 to 14 hours for making the part by normal methods.

The Giddings and Lewis system was first demonstrated in June, 1955. It has been in use ever since that time in the actual production of test pieces for various aircraft companies, but the most important job was the production of horizontal stabiliser panels for the North American F-100D Super Sabre.

The Bendix Aviation Corporation states that it entered the field of numerical control of machine tools because a division of the Corporation had a manufacturing problem to which this field offered a solution. The problem was to manufacture prototype models and production masters of three-dimensional cams for use in automatic fuel control systems for jet aircraft engines. The cams must be cut to an accuracy of .001" or .002".

Although copying machines were available, the production of masters by hand required 200 to 400 man hours, or a lead time of four to eight weeks. Moreover, the design of these cams is based on experimental data obtained from engine tests and, as changes are made in an engine from prototype to production models, the cam specifications are likely to change. Thus, long lead times on these cams for prototype engines could, and did, seriously hamper development programmes.

A numerically controlled machine was built and, with this machine, the lead time from design data to finished cam has been reduced to less than one week, as compared to the four to eight weeks mentioned for hand methods. Most of the lead time in the new system is consumed in preparing the tape.

The machine has now been in use on a factory floor for just over two years — ever since it was turned

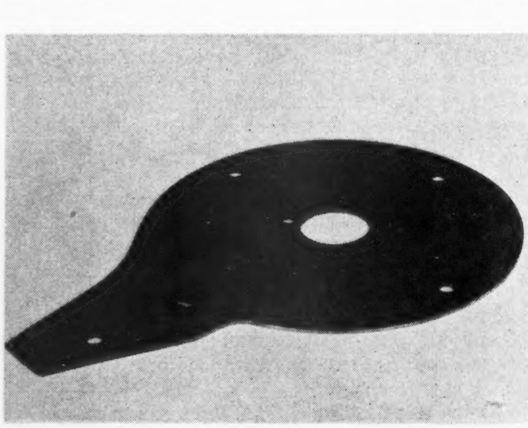


Fig. 5. Stainless steel flat cam cut on Research Engineers machine. Maximum diameter : 10¼". Thickness : 3/32".

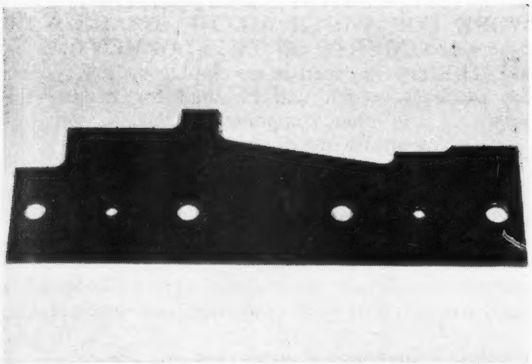


Fig. 6. Gauge plate lathe template cut on Cincinnati No. 3 Miller ($10'' \times 3\frac{3}{4}'' \times \frac{1}{8}''$).

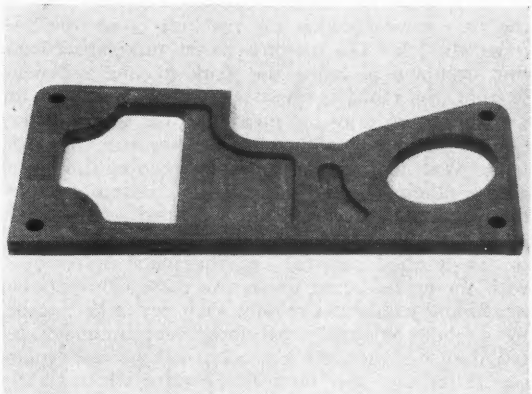


Fig. 7. Light alloy experimental piece cut on Wadkin Router ($10'' \times 4\frac{7}{8}'' \times \frac{3}{8}''$).

over to the division for which it was built. It has been operated on a two-shift basis by regular shop personnel.

Numerical position information is recorded, in coded form, on punched paper or plastic tape, or on punched cards. The work of translating information from the drawing to the tape, or to cards, is done by a programmer while the machine tool is in use on another job and, therefore, the machine can spend a maximum of time actually cutting. As an overall result, the saving in time, including that required to make the tape, can often be from about 60% to 95% and, for a further copy from the same tape, from about 80% to 98% depending upon the nature of the work though, obviously, there will be examples in which the saving, though worthwhile, is much less. Another advantage is that the programmer can be an expert in the properties of special high stress materials and can have expert knowledge of the feeds, speeds, tool forms and sizes and the lubricants required for machining them. This knowledge can be "built into" the programme. The machine operator then has only the responsibility for keeping the machine in good order, for properly fixing the work and removing it, and for using the prescribed tool and lubrication. Both time and money are saved because the machine, unlike a human being, does not become tired, bored or distracted. Moreover, when the lunch bell rings or if a tool has to be changed, the operator can switch off the machine with full confidence that he can start it again in precisely the same position, because the action of stopping the machine does not remove or destroy any information.

It is of interest to discuss the reasons why the new machines can produce parts more rapidly than is possible by conventional methods. When a part is machined by conventional methods in which the machine tool is operated by hand, without the use of masters or templates, the actual time spent in cutting metal is only a small proportion of

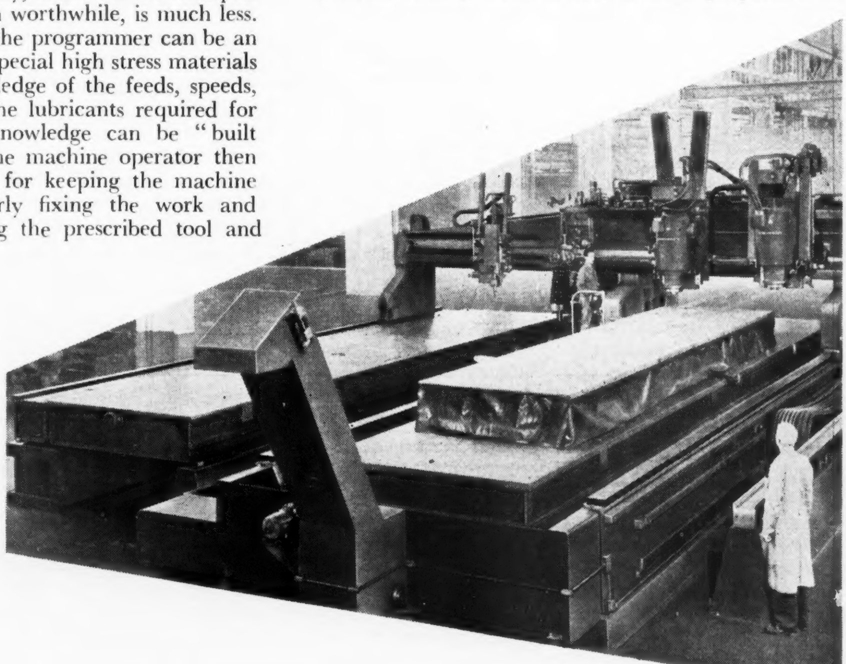


Fig. 8. Cincinnati gantry-type Skin Milling machine.

the time during which the machine is occupied in doing the job. The majority of the time, apart from that occupied in fixing the work to, and removing it from, the table, is spent by the machine operator in reading the drawing, measuring the work already done and making adjustments to the machine controls. With the new machines, the reading time is, of course, eliminated and the machine controls are automatically and more quickly adjusted. Moreover, when profiling, the path of the cutter relates directly to the finished pattern, i.e., the metal is removed with one or, for better finish, two cuts. Conventional machining techniques require each cut to be parallel to a slide axis and, therefore, very frequent re-orientation of the work is needed, together with many cuts. Thus, the use of numerical control, which greatly reduces the machining time for each job, means that fewer machines are needed. If, on the other hand, the part is one which is normally machined on a template controlled machine, considerable savings may again result. The cost of making a programme and the time required in which to do it are likely to be much less than that of making and setting up templates, particularly if numerical control is not used for making the templates. Moreover, the use of numerical control avoids the long and arduous job of setting up the templates. Thus, the saving of time between the provision of the drawing of a large and, possibly, complex part and the completion of the component concerned can be very great if numerical control is substituted for template control. In addition, the cost of the control equipment is sometimes less than that of the template table and its associated equipment.

WORK FOR WHICH MACHINES ARE NOW IN COURSE OF DEVELOPMENT

EMI is now engaged in developing control systems for machines which will be used for making the following, and other, components :

integral wings for aircraft;
spars and chords for aircraft wings;
gas turbine blades; and
ships' propellers.

Lathes and many special machines, such as those used for machining crankshafts, can also be effectively and advantageously controlled and my Company is likely to expand its work to include their development.

Aircraft Wings and Components

The Cincinnati Milling Machine Company has developed a gantry-type skin miller which is primarily intended for milling complete integral wings, but which can also make the tips and leading and trailing edges, or spars and chords for conventional wings. This machine, which has a large template table at one side and a smaller one on the other side, is shown in Fig. 8. Electronic numerical control equipment is being developed by EMI to operate the skin miller. It is interesting to note that the cost of the installed numerical equipment will almost certainly be less than that of the template tables and associated equipment which it replaces. The operating costs will also be less because the cost of making and setting up the templates is very much greater than that of devising the programme and punching the cards.

The work is mounted on a fixture which is itself mounted on the table. The fixture can be swivelled

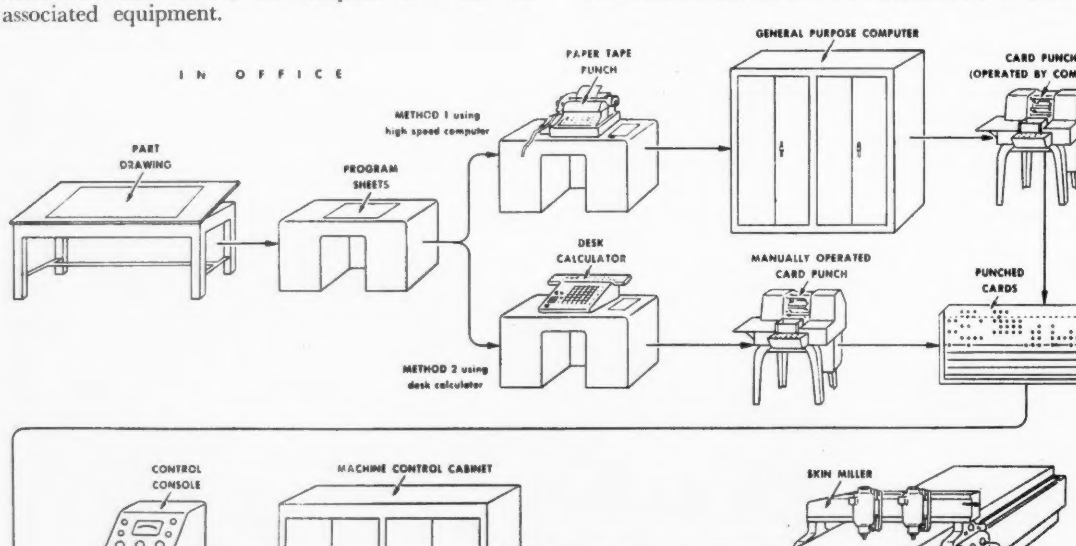
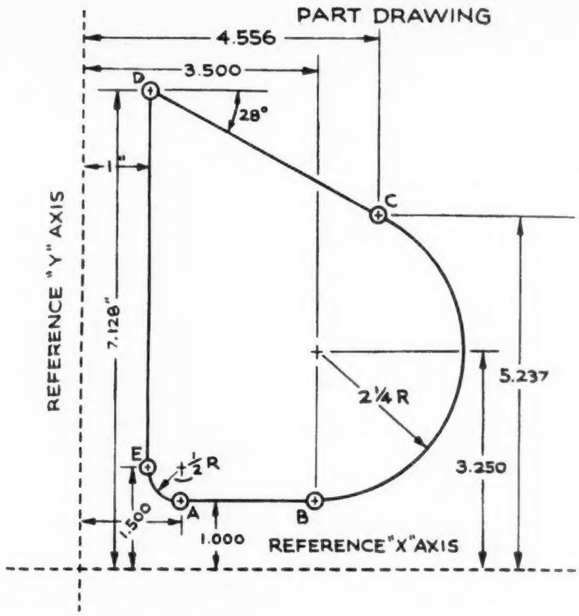


Fig. 9. Numerical control system for Cincinnati gantry-type Skin Milling machine.



SAMPLE PROGRAMMING SHEET

Section		End Point of Section			Informational Tolerance	Feed Rate In./Min.	Radius Inches	Cutter Radius Inches
		X	Y	Z				
START		01.500	01.000	05.000	0.001	—	—	0.500
A	B	03.500	01.000	05.000	0.001	50	—	0.500
B	C	04.556	05.237	05.000	0.001	50	2.250	0.500
C	D	01.000	07.128	05.000	0.001	50	—	0.500
D	E	01.000	01.500	05.000	0.001	50	—	0.500
E	A	01.500	01.000	05.000	0.001	50	0.500	0.500

PROGRAMMED NUMERICAL DATA

Fig. 10. Sample programming sheet for use with Cincinnati Skin Milling Machine.

through ± 20° and tilted longitudinally through ± 2°, or transversely through ± 8°.

Mirror Images

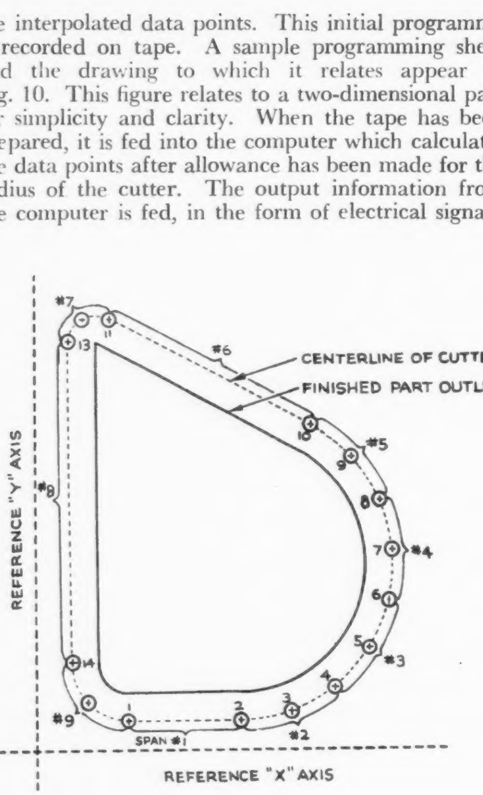
Milling operations are carried out by means of two spindle carriers which are mounted on saddles arranged for cross motion, on a travelling gantry. The gantry provides the *x* axis, while the cross motion represents the *y* axis. The motions of the saddles are controlled by a single voltage from the machine control cabinet. A reversing device may be inserted, if required, in the line to either saddle so that the saddles may travel in the same direction or in opposite directions if a mirror image is required to be made. Moreover, the spindle carrier motions can also be arranged to be mirror images in the vertical direction. These valuable facilities permit right- or left-handed skins to be made separately or simultaneously with the same programme. In certain cases, male or female dies can be made.

The Numerical Control System

A block schematic of the numerical control system is shown in Fig. 9, from which it will be seen that the final programme is recorded on cards and that two methods of card punching may be used. In Method 1, the information taken from the drawing is encoded on a paper tape. The coded data relates only to the position of junction, or blend, points of curves and straight lines and to the radius of each curve, together with the feed rates, the cutter radius and the tolerance to within which the computer is required to calculate

the interpolated data points. This initial programme is recorded on tape. A sample programming sheet and the drawing to which it relates appear in Fig. 10. This figure relates to a two-dimensional part for simplicity and clarity. When the tape has been prepared, it is fed into the computer which calculates the data points after allowance has been made for the radius of the cutter. The output information from the computer is fed, in the form of electrical signals, to an automatic machine which punches the cards. The output from the computer can also be presented in tabular printed form, as shown in Fig. 11, which relates to the same drawing as that of Fig. 10. The computer is not a special one and it may be used for other purposes. A typical computer, which is used for this work in the United States, is the IBM 650 Computer.

In Method 2, the necessary computations are carried out with the aid of a desk calculator and the cards are punched in a manually operated punching machine.



The Relative Advantages of a Computer and a Desk Calculator

It is difficult to reach any final and indisputable answer to the question whether it is better to use a computer or a desk calculator, or both. The answer depends not only on the amount and complexity of the work to be done, but on the personal feelings of the programmer and on the way in which the information is arranged in the drawing. It also depends on whether the calculation is largely arithmetic or whether mathematics are required.

Briefly, the situation is as follows:

The desk calculator is considerably cheaper than a computer but it is also much slower. It is as accurate as a computer but it requires human operation, which the computer does not, and this reduces its effective accuracy.

A big advantage of having a desk calculator in addition to a computer is that, with its aid, small changes to the shape of a component can rapidly

POINT CO-ORDINATES

CARD (SPAN) No.	MIDPOINT				END POINT				INTERPOLATOR SPEED R.P.M.
	Pt. No.	X_m In.	Y_m In.	Z_m In.	Pt. No.	X_e In.	Y_e In.	Z_e In.	
					1	1.500	0.500	5.000	
1	*	—	—	—	2	3.500	0.500	5.000	12.5
2	3	4.395	0.650	5.000	4	5.193	1.083	5.000	27.4
3	5	5.806	1.752	5.000	6	6.168	2.585	5.000	27.4
4	7	6.240	3.490	5.000	8	5.780	4.788	5.000	27.4
5	9	5.155	5.446	5.000	10	4.350	5.865	5.000	27.4
6	*	—	—	—	11	1.235	7.569	5.000	7.0
7	12	0.748	7.557	5.000	13	0.500	7.128	5.000	24.3
8	*	—	—	—	14	0.500	1.500	5.000	4.4
9	15	0.793	0.793	5.000	1	1.500	0.500	5.000	16.0

Note: * Indicates straight-line interpolated span. No midpoint required.

COMPUTED NUMERICAL DATA

Fig. 11. Sample of computed numerical data for use with Cincinnati Skin Milling Machine.

be made manually, but it may not be economic to do this with the computer. For instance, if the computer is serving several machines and, possibly, also doing payroll work, it may be in use when required for the small alteration. The desk calculator can then be used instead.

Punched Card Programme

The information is punched into a series of cards, either automatically when using Method 1 or manually when using Method 2. Each card includes x, y and z information relating to two new data points which, together with the last data point on the previous card, completes the span information.

The main numerical controls are:

- x Motion of the gantry;
- y_1 Motion of saddle No. 1 across the gantry;
- y_2 Motion of saddle No. 2 across the gantry;
- z_1 Vertical motion of spindle in saddle No. 1;
- z_2 Vertical motion of spindle in saddle No. 2;
- α Swivelling motion;
- β Longitudinal tilt;
- γ Transverse tilt.

Operation of the Control Cabinet

The three main co-ordinates which have to be dynamically controlled by the apparatus in the control cabinet are the x, y and z co-ordinates. At the end of each longitudinal cut along the wing, the x, y and z channels in the control cabinet are switched to the work fixture so that the necessary α, β and γ static information may be computed and the fixture swivelled, tilted and hydraulically locked in position ready for the next cut. Each of the dynamic information channels can be individually switched by the numerical control system to function in various ways. For example, each control channel may be automatic, with or without mirror images, manual or fixed.

Interpolation

The type of interpolation provided by the apparatus in the control cabinet can be numerically selected by the punched cards. The interpolation may be parabolic for providing curves, linear for producing straight lines, or it may be arranged to provide uniform acceleration to or from a stop.

Accuracy of the Work

It is expected that the numerically controlled Cincinnati skin millers will work with an accuracy, due to all causes, of the order of .010″ in the x axis for the full length of the table and of .002″ in the z, or vertical, axis.

Turbine Blades and Ships' Propellers

It has been of great interest to consider the automatic production of turbine blades because of the very small amount of information needed to define the complete blade, excluding the root and tip. Many designers specify only two sections of the blade, with consequently straight line fairing between them, but it seems that almost all blades can be described by three sections, with parabolic fairing, or interpolation.

The sections themselves can be specified by about 20 points round the edge or, even more simply, basic aerofoils may be used in conjunction with camber and twist angles. There is, thus, the attractive possibility of putting this very limited amount of information into a computer and using this same computer to produce the tape, or cards, required by the machine tool. It is, of course, possible to use any intermediate stage but the complete process, as sketched here, seems as near the ideal contribution of automation to the design of new products as can be conceived. A fact worth bearing in mind is that first tests frequently show the need for some empiric modification and, hence, a system which can accept small manual programme modifications may be very advantageous. Moreover, the provision of an automatic plotting table for sketching basic sections from the computed tape, is also advantageous.

Many of the above remarks apply, with a change of scale which does not alter the principle, to ships' propeller blades.

ADVANTAGES TO BE GAINED BY THE USE OF NUMERICAL CONTROL

It is of great interest to know what a famous company in the American aircraft industry thinks of numerical control, since they have more experience of its use than we have. Mr. K. G. Wood, of the Boeing Airplane Company of Seattle, has given permission for a short talk which he gave to an American Institute of Electrical Engineers' Conference on Machine Tools to be quoted here. Mr. Wood's audience consisted largely of designers of numerical control equipment.

"After witnessing a series of remarkable tests, I am convinced that numerical control will be of considerable value to the aircraft industry. I say this without qualification, for I have seen an aluminium profile part that once took 23 days to produce on conventional machines, planned, programmed and made in less than half-a-day. Three-and-a-half hours were needed to make this part with a conventional tracer machine. Using numerical control it was cut in 14 minutes, and far more accurately. Obviously, there is no need to define numerical control here, but I will explain the possibilities of numerical control in the aircraft industry. We believe these possibilities are extensive.

"In many respects, of course, the aircraft industry is not like other manufacturing businesses. While our companies have some of the largest manufacturing plants in the world, nearly all our products are built by custom techniques. Since real quantity production is never found in the aircraft business, it was natural that we considered automatic manufacturing, something that could be used only in factories producing can openers, refrigerators or automobiles. Up to the last couple of years, we had never given the idea of using automatic manufacturing any serious consideration.

"But today we are beginning to see the importance of numerical control to a large part of our manufacturing operations. We know that we can share in the valuable advances of the new Industrial

Revolution and produce complex things faster, better and cheaper.

"Our products require precise and efficient manufacturing methods. In addition, these methods must not be so rigid that design changes, on which we thrive, cannot be incorporated into the end product in a relatively short time. Performance specifications of aircraft are continually advancing and greater demands are made of our design engineers and, ultimately, of our manufacturing shops. Faster speeds, higher altitudes and better manoeuvreability require that our planes be stronger, safer and, in addition, built within slimmer and more streamlined shells. Aerodynamic smoothness and matching fits become more exacting with each succeeding model.

"This, of course, makes the job of our design engineers extremely difficult. Profound ingenuity is needed to design a reliable high-strength structure within a slim enclosure. But the design engineer's problems do not end with the completion of a theoretically workable design. For the design engineer must cope with the limitations of manufacturing techniques. He must adjust his design and often compromise it before the structure can actually be manufactured with the available machines. Numerical control will eliminate much of the need for such compromise for it improves manufacturing methods and techniques.

"There is a greater freedom in producible shapes and outlines and also the promise of a much finer control of finished dimensions. You are probably aware that the heat generated by friction at high speeds necessitates building planes with high strength materials such as titanium and stainless steel. Such planes are now in design and, when manufacturing begins, the problems will be bigger than those encountered in building today's planes. The heavier weights of titanium and steel make machined tolerances more exacting, since excess material will penalise the plane's performance more than it does with aluminium. Both tests and theory show that numerical control can provide closer tolerances than conventional machining methods. Consequently, numerical control strongly appeals to us.

"Other aspects of numerical control are also attractive: for example, we manufacture many parts but nearly always in small lot sizes. This requires frequent changes in machine set-ups. The flexibility of numerical control, the way a machine can be reset to produce a different part with ease and speed is very valuable to us.

"Of course, the aircraft industry will enjoy the same benefits of numerical control as other industries: the elimination of repetitious adjustments by the operator during the production of successive identical parts. And, of course, a numerically controlled machine, which was never distracted by a girl walking by, can produce identical successive parts with no dissimilarities. Human error, which is the lack of consistent good judgment, will be eliminated and the heavy cost of training people to operate the more productive machines of the future will be reduced.

"For our industry and, I'm certain, for many others, numerical control is really a new philosophy of manufacturing. For this new process will dynamically affect every aspect of production, from engineering concept and design of an individual part, to assembly of the finished product. Numerical control is more than a new way of operating a machine; it is a new and efficient way of operating a and processing data, of controlling fabrication machinery, and of regulating and controlling quality.

"A good example of the new and efficient way of planning and processing technical data that is now available through numerical control, is shown by a comparison of two methods of preparing a control tape for the profile part, mentioned at the beginning of this talk. Using desk calculators, planning and preparation of a control tape took 70 hours. Using numerical control computers, the control tape was completed in two hours; a time saving of 35 to one.

"Such time-saving, coupled with avoidance of human error in calculation and copying, renders the use of computers vital in data preparation for numerically controlled machines.

"That numerical control is an efficient way of controlling fabrication machinery is well known to you. The fact that numerical control will be an efficient way of regulating and controlling quality is evident in the research and development of numerically controlled inspection machines now in progress. With the aluminium profile part, only 14 minutes was required for cutting but inspection took 12 hours. It took 50 times longer to inspect for quality than to make the part. Certainly, here is an area for improvement. The fundamentals of numerical control should soon be incorporated successfully into automatic inspection devices that can rapidly verify the quality of a part and provide permanent printed records of inspection results. When that has been perfected, our industry will realise more of the benefits of numerical control.

"These three operations, the efficient planning and processing of data, the control of equipment and the rapid inspection of quality, constitute the new philosophy of manufacturing that could revolutionise a large part of our manufacturing operations.

"There are factors that will influence the rate of acceptance of numerical control by the aircraft industry. Many of these can be defined. Some can be controlled by the aircraft industry and others must be controlled by the manufacturers of the equipment. For example, is numerical control equipment reliable? This, of course, is dominant. Other questions are also fundamental to the question of acceptability. Is the equipment easily maintained? Is an extensive training programme necessary? Is the equipment durable enough for daily factory operation? Is the equipment of high quality, or is it breadboard circuitry in fancy cabinets?

"In the aircraft industry, we are well aware of the complexities involved in the design and manu-

facture of automatic equipment. We know there will be "bugs" early in the programme and that we will need the assistance of manufacturers in correcting early difficulties so that the first and most critical applications of numerical control will be successful. For successful early operations will indicate the phenomenal advantages that extended use will bring.

"The capital investment cost is also important to us. High pressure talk about potential will not sell numerical control to aircraft industry management if the initial cost is unreasonable, since early operating returns are only speculative. The rate of acceptance in our industry will be directly affected by the amount and kind of groundwork and preparation we do. Most of our companies today have started programmes of training, indoctrinating and familiarising management and personnel so that when the time is right for changing manufacturing methods, numerical control will not be a totally foreign subject.

"Similarity of systems, particularly data and memory storage forms, will also affect the rate of acceptance. I feel that the greater the similarity, the more rapidly our industry proper and our sub-contractor will accept numerical control. Any sub-contractor will be naturally reluctant to invest in equipment that is not compatible with the equipment used by the prime builders he serves. Compatibility of machines also helps the Government achieve mobilisation flexibility, a vital factor in realising a successful defence programme.

"To summarise briefly, our industry can see the outstanding advantages numerical control offers and we can safely predict a broad and fruitful application of it throughout our plants. Our products, without exception, are continually aiming at higher performance. Numerical control offers a sound way of building an airplane more closely to optimum design than ever before. Numerical control is more than a method of automatically controlling machines. It is a philosophy of manufacturing that affects the entire cycle of production, from the engineering drawing to the approved finished part. Data preparation and processing, automatic machine control and automatic quality control are the basic elements that, when combined, complement and supplement each other to form this new philosophy.

"We are anxiously looking forward to and planning for the day when numerical control will allow us to make better airplanes cheaper, and faster, than previously possible. Most of us are already laying the groundwork for the introduction of numerically controlled machines. Boeing's preliminary planning has been under way for several months already, and we expect to realise a large return on our investment relatively early. Numerical control will result in a scientific regulation of work-flow in many operational areas of the aircraft industry. I am certain that computers, servo-mechanisms and electronics can now be instrumental in our manufacturing, just as they have been important for many years in designing and equipping the 'flying machine'."

It will be noticed that the majority of the companies mentioned earlier in the Paper are American. It is usual for the sale of new devices to build up there more quickly than here, because customer reaction takes place more rapidly and, possibly, it is also exploited more rapidly. As a result, the following facts emerge and should be noted :-

1. The U.S. Air Force will not place orders for large machines, such as skin millers, without numerical control and it has already placed many such orders for controlled skin millers.
2. The Air Force, and the U.S. aircraft industry, expect to place many more orders, over the next few months, for other machines with numerical control.
3. Numerical control was considered sufficiently important for the last Annual Conference of the American Institute of Electrical Engineers to be devoted entirely to this one subject. It was at this Conference that Mr. K. G. Wood presented the Paper which the present writer has quoted.

SUMMARY

Numerical control of machine tools is in continuous use for research, development and production both here and in the U.S.A., though the extent of its use in America, particularly in the aircraft industry, is enormously greater than it is here. This situation must not be allowed to persist.

Numerical control can do many jobs which cannot otherwise be done. It can do more complex work much more quickly and better than is possible without it. The possibilities of numerical control are rapidly being envisaged and exploitation does not lag far behind.

ACKNOWLEDGMENTS

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R. E. SPENCER and R. VOLES. Brit. Prov. Patent No. 30448/55.

Further patents have been filed.

APPENDIX I

TYPES OF MACHINE TOOL CONTROL

Static and Dynamic Control

Numerical control may be static or dynamic in form. In the static case, the information fed to the machine relates to a succession of positions to which each slide is required to move and to wait while some operation is carried out. Static control is applied to jig borers, drilling machines and machines of similar type. With the aid of such a machine, the centres of holes may be marked, or they may be drilled, with a very high degree of positional accuracy. In order to increase the accuracy, the normal procedure of approaching each location from the same direction may be adopted so as to remove the effects of backlash if it has not been otherwise removed, as explained in Appendix II.

In its dynamic form, the information is used to keep the slides continuously moving, for contouring or routing operations, on milling machines and other machine tools of this sort.

It is a much more simple matter to make a machine operate in a static manner, because motion from one static position to another does not have to take place over a prescribed path. Overshoot is of little importance since it will automatically be corrected before the table is locked and machining starts. In the dynamic case, however, neither of these ameliorations exists.

In order to provide dynamic numerical control, the relative path of the work past the cutter must be accurately defined. The definition of the path involves, at least, defining the horizontal motions in polar or, more usually, in cartesian co-ordinates and, for three-dimensional work, also the rise and fall of the cutter. Moreover, for making more complex parts, it may also be necessary to define a certain degree of tilting and swivelling of the work or of sideways, and forward and backward, tilt of the cutter. These defined motions must be presented to the machine tool in the form of coded instructions.

Methods of Computation

It is probably well known that there are two types of computing that can be used for machine tool control; these are analogue[1] and digital[2] computation, and they are so-called because the terms denote the forms in which information is presented. This is not the place to discuss them in detail but it may be of interest to know that EMI has adopted the analogue method and has developed its own special system. There are three main reasons which lead EMI to follow this course ; they are as follows :-

1. The use of analogue control makes it possible for the control system to be position-conscious instead of increment-conscious, although it would be possible to make a position-conscious digital system by using the cyclic progression binary code and a suitable position measuring disc. Thus, if the machine settings are moved while it is not under control, it will return to its correct setting when control is resumed. This permits the control to be interrupted, for example, to change the cutter, without loss of registration except for the length of the tool projection from the cutting head. However, this registration may be regained by using a gauge to ensure that the tool projection is correct or, when the facility is provided, it is possible to turn a knob on the machine to compensate for any error.
2. The system is complete in itself, i.e., tape, punched with salient dimensional information, can immediately be inserted into the machine and the part can be cut. Thus, it becomes possible to make immediate minor changes in a complex programme without recourse to a large computer.
3. It is only when analogue control is used that it is practicable to compensate for the cutter diameter *at the machine*. Cutter diameter compensation can be calculated by the computer used with a

1. Analogue representation, which involves using one quantity to represent another, can vary smoothly between any two values but is limited in ultimate accuracy by the stability of the components used. This is of no importance provided it is superior to the accuracy of the end-product which, in this case, is the machine tool. Analogue information is not numerical information but may be generated from it.
2. Digital information is numerical information in which the least significant digit cannot alter by an amount less than one, i.e., a digit of still smaller significance may not be used. Thus digital quantities can change only in discrete amounts.

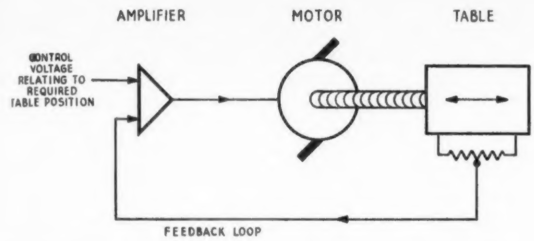


Fig. 12. Block schematic of a closed feedback loop.

digital machine but, once the programme has been produced, the degree of compensation cannot be altered without again having recourse to the computer to make a complete new programme. Since the computer is an expensive item, some users prefer to make use of a computer service and the cost, and possible delay, involved in making a new programme becomes a grave disadvantage.

The EMI Method of Analogue Control

Since the dimensional information on a drawing is discrete in nature, the instructions are quoted, in the EMI analogue system, as successive positions[1] to which the work and the cutter are to move, and an interpolation process is carried out in order to provide smooth curvilinear motion instead of progression by leaps and bounds. The work of translating the coded information and of interpolation, so as to provide control signals, is done in a control cabinet whose output voltages are continuous analogue representations of the required motions of each movable part of the machine tool. The apparatus in the control cabinet thus converts the, necessarily, digital information taken from the drawing into analogue positional control information for the operation of the machine.

The Use of Feedback

Since it is necessary to ensure that the relative motions of the work and the cutter are in accord with the instructions, it is also necessary to measure continuously the relative positions of the work and the cutter, and to feed this information back to the servo motors, *via* devices which compare the resulting positions with the original instructions, and so cause the errors to be eliminated. For obvious reasons, a system which does this is known as a feedback system or a feedback loop. Feedback loops may be open or closed; an open loop being one in which a human operator forms part of the system. Fig. 12 shows a closed feedback loop in which a voltage representing the required future position of a work table is fed, *via* an amplifier, to a servo motor which rotates a leadscrew and so drives the table. A device, indicated by a potentiometer for simplicity, is fixed to the table and supplied with a constant voltage across its ends. A contact, which is fixed with relation to the bed of the machine, slides over the surface of the potentiometer when the table moves and picks off a voltage which is passed *via* the feedback loop and applied to the amplifier in a sense opposite to that of the instruction voltage. Thus, if the two voltages are equal, the table must be in the correct position and the input to the amplifier, and hence its output, will be zero and the driving motor will not run. If, however, there is an error in the table position, or if the instruction voltage changes, the motor will operate in the correct sense to remove the error or to drive the table along its correct course at the appropriate rate. In practice, the potentiometer is replaced by one of a large number of highly accurate position measuring devices according to the purpose for which it is required and the maximum traverse which has to be measured. Alternatively, the feedback system may be arranged to measure the angular rotation of the driving mechanism, which may be a leadscrew.

Information Content

It has become conventional to refer to sideways motion of the work towards the left as positive motion in the x direction. Motion towards the operator is known as positive y motion and upward motion of the cutter as positive z motion. By using this artifice, the dimensional information on the drawing may be read by taking all measurements from a point of origin lying outside the work and adjacent to the near left hand corner of the work table. The dimensions relating to the x, y and z co-ordinates of successive points on the surface to be machined are codified and recorded, in that sequence, on a paper tape, or on cards, by punching holes in predetermined positions. The hole positions, when using tape, form a binary representation of each decimal digit but, on cards, they may be otherwise coded.

The tape, or cards, are fed into a reader which reads the information relating to the first dimen-

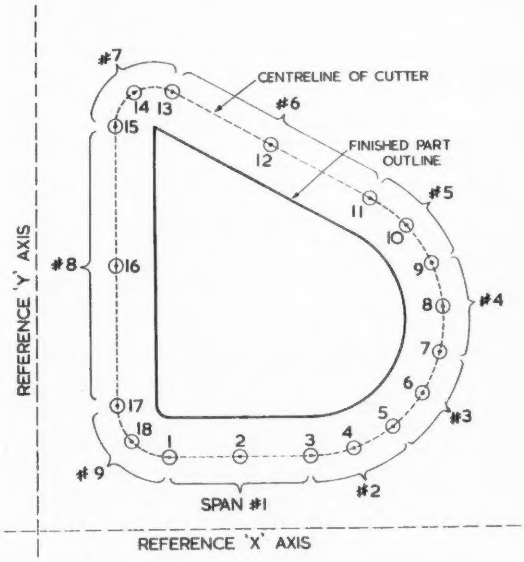


Fig. 13. The use of spans in preparing a tape.

1. It should be remembered that, in some digital systems, the instructions are quoted as *increments* of position.

sional data point and passes it to three different sets of information stores, there being one set for each direction of motion. This information, which is held in the stores until required for use, represents only one point on the surface to be machined and, therefore, it contains no information as to the direction in which the work-table will be required to move. To acquire this, it is necessary to have information regarding two successive dimensions or data points; in practice, three-point information is used to establish curvature and since, in order to avoid discontinuity, new information must be available before the old is discarded, five-point information stores are provided. It is, thus, necessary to feed in information relating to the three data points, x_1 y_1 z_1, x_2 y_2 z_2 and x_3 y_3 z_3 before the machine tool starts to move from the point of origin to which it has already been brought by an " alignment stop " signal, which may be recorded on the instruction tape or cards.

Preparation of Instructions on Tape

The method of transferring the drawing information on to tape is as follows: Fig. 13 shows the drawing of a part to be made; only two dimensions are shown, for simplicity, but the process is similar when there is a third dimension. Each successive pair of intervals between dimensional data points is known as a 'span'. Thus, points 1 to 2 and 2 to 3 form one span, while 3 to 4 and 4 to 5 form another. The dimensions must be quoted at places where there is a corner, an inflection or a blend point; these are known as 'major' points and they are odd-numbered. An intermediate, or 'minor' point must be quoted between each major one[1]. In addition, allowance must be made for the radius of the cutter, since the path to be defined must normally be that of the centre of the cutter. A list of the dimensions is then tabulated. The cutter (z motion) may be programmed to be withdrawn from the work at the point of origin and lowered before reaching the work, or it may be lowered before reaching the origin, as desired. If an end mill is used, the cutter may be brought on to the workpiece at any point on its surface. The workpiece must be located with respect to the origin in accordance with the data punched in the tape.

The dimensional information is recorded on the tape in the decimal binary code. The binary code is based on powers of 2 and is a method of representing numbers by a series of noughts and ones; it is particularly suitable for a punched code because noughts can be represented by the absence of a hole and ones by the presence of a hole. The code, as used by EMI for punched tape, appears in Fig. 14 which shows the code for numbers up to nine. In the decimal binary code, each digit of the decimal number is sequentially recorded in terms of the code, beginning with the most significant digit preceded by sufficient noughts to make each dimension have five digits. Any number of digits may, in different circumstances, be used but, in most cases, five are

1. It should be noted that Fig. 13 is similar to Fig. 10 but that the latter omits the mid-point on linear spans.

BINARY CODE

Number or Sign		*Binary Representation* $2^3=8$	$2^2=4$	$2^1=2$	$2^0=1$
0		0	0	0	0
1		0	0	0	1
2		0	0	1	0
3		0	0	1	1
4		0	1	0	0
5		0	1	0	1
6		0	1	1	0
7		0	1	1	1
8		1	0	0	0
9		1	0	0	1
Alignment Stop (14)		1	1	1	0
Stop (10)		1	0	1	0
Error	1				

Note that 1 represents a hole and 0 the absence of a hole. The error signal lies in a separate column used only for this purpose.

Fig. 14. The Binary Code as used for the preparation of tape for use with the EMI analogue system of numerical control.

used; these can, for instance, represent dimensions up to 99.999", i.e. nominally 100", measured to the nearest thousandth. The decimal points are not recorded and no space is left between successive data points, the tape being read in blocks of five punch positions. A line of small holes is provided near the centre of the tape, and this is engaged by a feed-wheel to move the tape forward by the correct amount.

Inaccuracies in the size and precise position of the letters in a line of type do not normally affect our ability to understand the meaning expressed. In the same way, it is only necessary that the holes should lie in the correct column across the tape; their size and position along the length of the tape are not of vital importance.

The data is recorded on the tape with the aid of a modified teletypewriter. The punched tape issues from the side of the machine and the data which has been recorded appears on a sheet of paper which protrudes from the top. Thus, each value can be checked as it is punched and, if an error occurs, depression of an " error " key punches holes which cause the tape reader to ignore the record. Fig. 14 includes an error signal together with an alignment stop and a stop signal. Note that the alignment stop brings the work and the cutter to the origin or any other desired position and stops the machine. The stop is used at the end of the run or, for example, when it is required to programme a change of cutter.

Operation of the Control Cabinet

The control cabinet contains the following apparatus:

1 Tape Reader;
3 Five-point stores (x, y and z);
3 Interpolators (x, y and z);
3 Servo Amplifiers (x, y and z);
1 Cutter Diameter Compensator; and
1 Power Supply System;

together with the necessary switches for controlling the flow of information through the correct channels.

This apparatus is designed to interpolate additional data points, to supply analogue voltages and accept feedback signals and to compare these in the servo amplifiers and pass the difference to the servo motors to drive the machine tool.

When instructions numbered 1, 2 and 3 for each of the x, y and z directions have been read by the reading head and passed into the appropriate stores, the apparatus in the cabinet calculates a further 768 interpolated points between each pair of instructions, i.e., 1,536 points per span. The apparatus calculates these interpolated dimensions on the basis of a parabola through the three points denoting one span, and this can, in most cases, be relied upon to be a close approximation to the wanted curve. By breaking curves down into several spans, any desired accuracy in the fit of the parabola can be obtained. The points should be relatively closely spaced on each side of a point where a change of curvature occurs and, particularly, where the curvature changes rapidly. The more accurately a curve must be reproduced, the greater should be the number of points recorded while, obviously, points lying on a straight line may be widely spaced.

The reason for requiring the stores to be capable of storing information relating to five successive data points in each co-ordinate may be elaborated, as follows. When the work has moved to a position just beyond the first point in the span, the tape reader automatically moves forward to read dimensions numbered 4 and 5 to complete, with number 3, the information for the second span. When the work has passed just beyond the third or major point, the information relating to points numbered 1 and 2 are no longer needed and this part of the store is reset to receive information relating to points 6 and 7. The tape reader again moves forward to read this information and to insert it in the store. A continuous re-cycling operation of the stores thus takes place, with used information being dropped and new information being inserted. The actual rate at which information is read from the tape is, thus, dependent upon the setting of the speed control but, when the data points are closely spaced, the reader moves the tape more rapidly.

Cutter Diameter Compensation

If the cutter is not of the diameter used when making the programme or if it is desired to make a finishing cut, without using a cutter of a different diameter, it is only necessary to readjust the cutter diameter compensation device. A section of the apparatus in the control cabinet continuously calculates the normal to the curve being cut, and the cutter is moved in or out along the normal, in accordance with the setting of the knobs and the oversize-undersize switch. This facility is of extreme importance, because the rate of wear of the cutter is high with many of the materials which must be used for aircraft production. It provides one, of several, advantages of using analogue, rather than digital, control for machine tools.

Accuracy of the Work

The accuracy of any system is dependent upon a number of mechanical factors, even though the information about the relative positioning of the cutter and the work is correctly transmitted to the servo system. Particularly when the feed rate is high, the cutter position may be modified by dynamic lag in the servo system, by cutter deflection, work deflection or the effects of the presence of swarf, and by the fact that the effective cutting diameter of the cutter depends on the feed rate and on the material being cut.

In spite of these and other causes of error, it is possible to provide static positioning for use with a jig-borer to within .0001″. With dynamic machining operations using the Wadkin and Cincinnati Hydrotel machines shown in Figs. 3 and 4, at low speeds, the error can be kept to within one or two thousandths of the programmed dimensions for parts up to 10″ or so in size, but the tolerance increases with the dimensions and the feed rate. The consistency is normally superior to the absolute accuracy. For the cam milling machine shown in Fig. 1 the accuracy is within .001″ and is consistent to within a few tenths of a thousandth. The Cincinnati No. 3 machine, shown in Fig. 2, is accurate to within .003″ and is consistent to better than .001″. When machine tools have been improved, as suggested in Appendix II, the accuracy of the work will increase. In the meantime, however, the accuracy is as good as, if not better than, can be realised without numerical control and the consistency of the resulting product is a great deal better.

APPENDIX II
MECHANICAL PROBLEMS IN THE DESIGN OF MACHINE TOOLS

The design and construction of a machine tool may result in a machine which is perfectly satisfactory for manual operation, but which may prove to fall short of the standards required for numerical control.

It is, therefore, interesting to note the procedure which is followed when a machine is operated by hand. Only one slide is normally moved at a time, all the others being locked so that good standards of squareness are retained. The machining process is stopped before it is completed and the work is measured before a final light cut is taken so that, for the final cut, distortion of the machine and its cutter is reduced. The effect of backlash is removed by operating each slide in one direction only while machining one part. Even in the case of a jig borer, not only must the dials be adjusted to read correctly, but the settings must be approached from a particular direction and extremely slowly and smoothly if the requisite degree of accuracy is to be achieved. However, for dynamic numerical control, every slide must be able to move simultaneously and with varying directions and velocities, so that it becomes essential to reduce all forms of hysteresis to a minimum.

Hysteresis results in the position of a worktable, or other device, relative to that of the driving mem-

ber, becoming dependent upon the direction in which the motive force has been applied. It may be caused by those inelastic effects (sometimes called "bang-bang" effects) which are the result of loose fits, and by elastic distortion effects resulting from compression, tension, twisting and bending.

The inelastic effects are particularly troublesome because they have an adverse effect on the servo system, and because they increase with time due to wear. Improvements in machine tool design and construction, such as a reduction in slide friction, do not, in general, reduce the inelastic effects, although this reduced friction does reduce wear. They can be reduced, or eliminated, by the use of the technique known as pre-loading but, in general, the elastic effects cannot be reduced by this means. It is very important to appreciate these facts.

Although backlash can be eliminated from a leadscrew and nut combination, it is impossible, because of the existence of elastic distortion, to make a system in which there is no lag on reversal. An effect, which upon consideration is obvious, and which is not negligible, is that the leadscrew can, and does, compress and extend as the load changes from pushing to pulling, or *vice versa,* on reversal. This is, however, an elastic effect and, in common with other elastic effects, it can be reduced by proper choice of the cross-section and of other dimensions. Elastic effects do not increase with time and they are generally reduced when the load is reduced, as, for example, by reducing the slide friction.

Inelastic Effects

Inelastic effects may be removed by perfecting the fit of all moving parts. Backlash between a leadscrew and its nut may be eliminated by using two recirculating ball nuts, preloaded to an amount which exceeds the maximum operating load. Backlash can also occur if there is any possibility of longitudinal motion of the leadscrew as a whole. Unwanted table motion may be prevented by paying meticulous attention to the accurate fitting of all slides, by ensuring that the ratio of their length to distance apart is adequate and by the extension of kinematic principles to slide design.

Elastic Effects

Although the existence of elastic deformation is well known, the extent to which it contributes towards lost motion does not seem to be appreciated. For example, measurement of the elastic deformation of a table- and a saddle-leadscrew on a certain milling machine gives the following results:

The table-leadscrew outside diameter was $1\frac{1}{2}''$ and its core diameter $1\frac{1}{4}''$. A force was applied which was just not sufficient to overcome the stiction of approx. 250 lb. and the deformation, measured at a distance of four feet along the leadscrew from a fixed reference point, was found to be .00033" so that, when reversal is included, a total deformation of .00066" results from this cause alone.

A similar measurement on the saddle leadscrew, of $1\frac{3}{8}''$ outside diameter and $1\frac{1}{8}''$ core diameter, made at a distance of two feet from a fixed reference point, when the stiction load was 500 lb., showed a total deformation of .0008".

The elastic effects include those mentioned below:

Compression or tension in	Leadscrews; Ball bearings; Bearing housings; Pistons; Gears; Shafts, and
Twisting and bending in	Cutters; Leadscrews; Bearing housings; Pistons; Shafts.

If longitudinal motion of a leadscrew is inhibited at both ends, by preloading to an amount which is greater than the maximum working load, the compression or tension will be reduced to 25% of the value obtained when one end of the leadscrew is free to float. It will be obvious that the use of preloading must not result in too great an increase in friction and therefore ball bearings must be used. The bearings must be of adequate size to withstand the applied force without undue compression.

Twisting and bending may be reduced by the use of integral construction wherever possible. The use of parts which are bolted on to other parts is a frequent source of distortion when a load is applied to them. The axes of leadscrews and pistons should lie midway between the slides of the tables or rams which they drive, and on a straight line joining the centres of the slides. Twisting and bending of cutters is improved by keeping them as short as possible, but attention must also be given to the shanks or collets used for fixing them to the cutting head. All bearing mountings must provide an accurate fit for the bearings and they must be exceedingly rigid if they have to withstand any longitudinal or sideways pressure, especially if, as is usual, the pressure is a varying one.

All these matters are receiving the special attention of progressive machine tool makers, particularly those whose machine tools are being numerically controlled.

APPENDIX III
PROBLEMS IN PROGRAMMING

The art and science of programming are still in their infancy in spite of the vast progress which has already been made. However, many problems still remain in making a programme for a machine tool and the problems differ according to the method of, and equipment used for, carrying out the computation. Both the analogue and digital systems start with information on a drawing, but it is possible to present the information in various ways, some of which are more suitable for one system and some for the other. For this reason, a study of the methods of information presentation on drawings has been, and is continually being, made by many workers.

These studies require the expert attention of mathematicians, draughtsmen and production engin-

eers. A sound knowledge of the imperfections of machine tools, of all the properties of metals, cutters and lubricants and of metal-cutting techniques, as well as of numerical control systems, must be available to an investigation team if it is to achieve a real improvement.

In order to control a machine tool, it is necessary to define the path of the centre of the cutter with respect to the work, but this may be achieved in a variety of ways. In most digital control systems, the digital information on the drawing is presented, in coded form, on a punched paper tape. This tape is then fed through a tape reader which feeds the encoded information into a large computer whose output consists of a record, on magnetic tape, of equal increments of motion of each slide. This tape, when fed into a control cabinet associated with the machine, determines the incremental motions of the slides.

In the cases of analogue control systems, the digital information on the drawing is also presented, in coded form, on a punched paper tape. The tape, however, is usually fed, not into a large computer, but directly into the control cabinet where an interpolation process is carried out to provide signals which determine the instantaneous positions of the slides. Nevertheless, although for most purposes a separate computer is not required, it is useful to have one for very complex workpieces, since it can save much of the programmer's time. On the other hand, the computer need not be specially purchased since it does not require to be designed for this purpose. A computer which is used for payroll, or other purposes, may be arranged to do this work also.

The problems of programming arise mainly because of the need to simplify the job, to reduce the time required to do it and, as far as possible, to remove the risk of error. In order to achieve these objects, the information must be processed as little as possible by human beings and the work placed on the broad shoulders of a computer, or an interpolator. It is most unfortunate that no one has yet succeeded, or probably even attempted, to make a machine to read a drawing so the human link cannot be eliminated. All that can immediately be done is to simplify the programmer's task.

This simplification of the human work to be done in preparing the initial coded tape can be partially met by arranging a standard procedure which is yet sufficiently flexible to suit a variety of jobs. The use of several standard forms on which to calculate various shapes of cutter path, in which the individual steps in the calculation are pre-printed, can save much time and reduce the risk of error. A standard form on which to write the dimensional information for each co-ordinate in every span will also be found useful.

The Four Stages of Programming

Four different stages are involved in the operation of programming or, at least, in the process of changing the information, as it is on an original drawing, into a table of figures which can be punched straight on to tape, or cards. It is assumed, for this purpose, that the drawing is not one which has been specially prepared for numerical control, but one which has been supplied by, say, a customer who wants a part cut as quickly as possible.

The first stage in the programme is to reduce the drawing to a standard form. This involves, at the very least, choosing a common origin for all co-ordinates and, in many systems, it also involves the explicit determination of all blend points between straight lines and circles, and so on. Since normal drawing procedure includes a variety of methods for indicating the position of a circle and how it joins up with neighbouring parts of the profile, this reduction can involve a considerable amount of work on quite a simple drawing. This condition should not be tolerated indefinitely since it requires extra non-creative human labour.

The second stage is that of arithmetic subdivision of the basic profile ; work which is required to a very varying extent in different systems. Thus, the original M.I.T. — Giddings and Lewis system requires all curves to be broken into straight lines, while the present EMI system requires that curves should be divided into sections which are short enough for parabolas to represent them adequately.

The third stage relates to a class of work which is a very difficult one to define. It comprises all those factors that only experience can dictate, such as the right feed rate, the effect of feed rate on tool deflection, the amount by which a blending radius-centre should be displaced to counteract the tendency of the cutter to dwell, the effect of the work material on the effective cutting diameter, and so on. It is our experience that this stage is a very lengthy and a very necessary one. For instance, it must not be thought that the cutter path is always a fixed distance from the cut face since, as an example, when proceeding past a corner the cutter should always leave the finished surface to avoid damaging the corner. The path traced by the cutter at a corner may be part of a parabola, or closed loop, or even some other more complex shape, as dictated by expediency or for some other special reason. Fig. 15 shows two methods of proceeding past a corner.

The fourth stage is the comparatively elementary one of coding, i.e., arranging the dimensions in the right sequence and adding in the necessary codes for starts and stops, changes in the type of lines or type of interpolation, or identification of the co-ordinate, as may be required by the various systems. The work involved in this stage tends to grow in magnitude as the others are reduced. Some people are familiar with the appalling amount of apparently meaningless gibberish that goes to make up the programme of a big digital computer, and also with the immense amount of information contained in it.

Some reduction in the volume of work in the third stage is likely to result when the, at present intangible,

factors concerned are numerically analysed and made subject to computation.

The amount of human effort in the second stage is to a large extent a matter of cost. One system may spend a great deal of money on a large computer to reduce or eliminate it ; others may provide the alternative arrangements of manual or computer programming, at differing costs.

The present need for the first stage of reducing the drawing to a standard form is much to be deprecated, because it demands an amount of trigonometry which many draughtsmen and planning engineers do not possess. Doubtless, technical education should be such that they do have it but, at the present time, they often do not. All available systems suffer from too much work of this type. It is in this connection that a recent M.I.T. suggestion is very interesting, because it allows for enormous flexibility in the specification of contours.

The New M.I.T. System of Programming

The system is based upon a novel method of defining successive configurations on the drawing, together with the location of points, instead of defining the location of various junctions between the configurations, together with the centres of circles. The method is shown in the table below :

DEFINITIONS

POINTS	
By co-ordinates	*p1 = –2.738, 10.372*
As the intersection of two lines	*p2 = s23/s7*
As the intersection of a line and a circle ...	*p3 = Ns2/c2*
As the intersection of two circles	*p5 = Nc3/c5*
	p6 = Fc2/c7
On a circle, at a given angle with the positive *x*-axis	*p7 = c2/83.074°*
LINES	
By two points	*s1 = p2/p9*
Through a point and tangent to a circle ...	*s2 = p3/Tc2*
	s3 = p7/Ac9
	s4 = Tc7/p4
	s5 = Ac6/p5
Tangent to two circles ...	*s6 = Ac2/Ac3*
	s7 = Tc4/Ac5
	s8 = Ac2/Tc7
	s9 = Tc12/Tc6
Through a point, at a given angle with positive *x*-axis	*s10 = p7/–73.215°*
CIRCLES	
By centre and radius ...	*c1 = p2/2.7405*
Centre, tangent to another circle	*c2 = p2/Tc4*
	c3 = p5/Ac7
Centre, tangent to a line	*c4 = p5/s2*

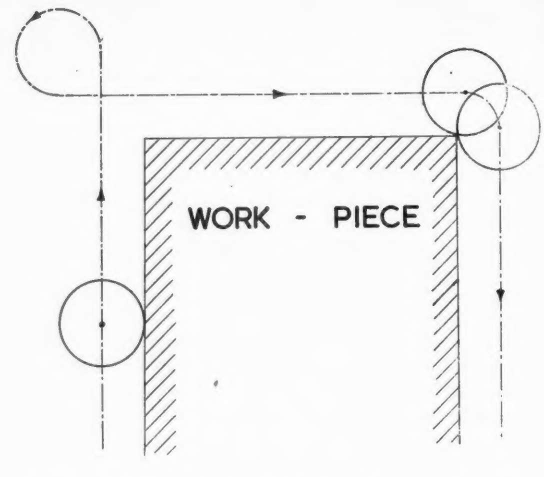


Fig. 15. Two methods of programming for the cutting of corners.

As in other methods of programming, each point, line or circle is designated by a separate symbol, *p* being used to designate a point; *s*, a line ; and *c*, a circle. To prevent ambiguity, circles and lines are given arbitrary positive and negative directions and if a circle cuts a line at two points, the required junction is defined by referring to the "near" or "far" intersection as required. The positive direction of a circle is clockwise and the determination of near or far is obtained by starting the circle at the point where its x value is a minimum. Thus, *p1 = Ns1/c1* means that point 1 is at the near intersection of line s1 with the circle c1. The direction of a line is defined as from the first to the second point, thus, *s1 = p2/p9* gives its positive direction. A line defined as passing through a given point at an angle with the positive x axis has its positive direction away from the point.

It is unnecessary to describe the system fully since those who wish to study it may refer to the literature.*

Enough has been said to show the radical departure from present practice which the new method represents and to show how it may remove the need for preparing the drawings in a special way.

* A. Siegel "Automatic Machine Tool Programming" Control Engineering, October, 1956, page 65.

REPORT AND DISCUSSION

Chairman : J. B. TURNER, M.I.Prod.E.

The **Chairman :** I am as keen as you all are to hear Mr. Puckle, of E.M.I. Ltd., expound the mysteries of numerical control. To most of us, it is something about which we have read in the technical press or have seen demonstrated at the Machine Tool Exhibition, but of which we have little practical experience. The claims made for the time saved and the accuracy achieved by this type of control are such that we must follow it up. Mr. Puckle is well known in the electronics world and is a distinguished member of the Institution of Electrical Engineers. He is the right man to put the subject across to us.

(*Mr. Puckle then presented his Paper, which appears on pages* 169 - 186.)

Mr. H. A. Chambers, M.I.Prod.E. (*General Manager, Rockwell Machine Tool Co. Ltd.*) : It is a pleasure to open the discussion on such a vital and interesting Paper. We all use machine tools in various forms, and this is research of a very high order. The progress is astounding. The time savings which Mr. Puckle has given in his Paper are really worthwhile. They should encourage anyone to investigate these methods. I hope his Company will receive the just reward of being encouraged in the use of these machines.

We have not heard about forgings in this Conference. I feel that if the method could be used to produce, cheaply and quickly, forging dies and if there could be greater use of heavy hydraulic presses to enable us to produce accurate forgings to be finished by this method, it would be another very great step forward.

In regard to accuracy, I am wondering whether from stage to stage in the use of this equipment progressive synchronisation takes place, so that there is no accumulation of error at the end of the run of the cutter. Perhaps Mr. Puckle will deal with that later.

I am grateful to Mr. Puckle for going into detail about numerical and digital systems. I am sure a lot of people, like myself, would like to know more about these two systems and, indeed, other systems. I understand that the M.I.T. system has a greater number of channels than we have produced in this country, even going to the point that they get audio instructions for the operator, which appears to me to mean a great saving in cutter life in that you can avoid damage due to the cutter being blunt or rising steeply.

Mr. Puckle : I thank Mr. Chambers for his remarks.

With regard to dies, some work is being considered, and I will ask Mr. Booth to deal with that part of the question.

With regard to cumulative errors, that is not likely to happen except, possibly, as a result of wear of the cutter, because the analogue system is based on measurement of position. As far as wear of the cutter is concerned, cutter regrinding or replacement periods can be coded into the tape.

Mr. R. H. Booth, B.Sc. (*Technical Manager, Industrial Applications Division, E.M.I. Engineering Development Ltd.*) : I do not think there is any reason why dies for forging or any other purpose should not be made by numerical control. We have tried to start with simple things like templates, intending to continue with more and more complicated cutting operations. Dies present no essential problems, but as you increase the number of control dimensions and get on to more complicated dies, the problems of programming and specifying what you want, in terms of numbers which can be put on a tape, increase rapidly. A lot of work is required before one can take a drawing of a complicated shape for a die and run straight into the tape with it. It is one thing to make a die of a simple shape, but it is another thing to make one for a complicated shape. It is easy in the case of a turbine blade, where there are mathematical expressions for the curves. Machines are being conceived all over the world with three, four, five, six and seven dimensions, but I think it will be a little while before more than three dimensions are used accurately, because of the difficulty of programming.

With regard to synchronising, if Mr. Chambers means to ask whether the progress of the work can be synchronised with some change such as the progressive wear of a cutter, the answer would be that in many cases cutter wear is not a major factor, but where it is, the control cabinet can be adjusted for the effect of the diameter of the cutter and that can do much to help. I am not clear about the extent to which cutter wear of dimensional significance can take place without first affecting surface finish. I feel that often surface finish deteriorates as a dimensional change appears. In the future, one

should look forward to automatic sensing of the cutter diameter. At the moment it is a matter of automatically checking the cutter diameter, and there is no means of automatically sensing the effective cutting diameter of a cutter. Also, a cutter has not always an obvious diameter. There is always some deflection of it. Its effective diameter depends on what it is cutting and upon the feed rate.

Mr. R. S. Brown, M.I.Prod.E. (*Director, Bristol Aircraft Ltd.*) : I read the Paper with great interest. In the aircraft industry we have been sold the idea for some considerable time that the numerically controlled machine tool will be of great help to us in our model shops and other places. However, Mr. Puckle mentioned mostly machine tools of American make. I wonder whether the people actually bringing out this control have sold it to our own machine tool industry, because we cannot get the dollars to buy American machine tools and at the present moment there seems to be no progress in this country in manufacturing machine tools which will take this control.

Mr. Puckle : We have made arrangements with the Cincinnati Milling Machine Company. They have a branch in this country which makes some of the smaller tools and, therefore, presumably one does not have to spend dollars to get them. The fact that we have an agreement with the Cincinnati Milling Machine Company does not prevent us from providing information in respect of, or fitting the control to, machines made by a British manufacturer.

Mr. Booth : There is nothing in our arrangements with any company which prevents our working with any machine tool company outside the United States.

Mr. Brown : I asked whether you in your sphere had made approaches to the British machine tool industry to see whether they could bring out machine tools which would fit your control.

Mr. Booth : One answer to that is that in the Paper there are photographs of three machine tools fitted with E.M.I. control, and all those machine tools were manufactured in this country, one by an entirely British Company, Research Engineers Ltd., one by the Cincinnati Milling Machine Company in Birmingham, and one by Wadkin Ltd., another entirely British Company.

Mr. W. S. Hollis, B.Sc.(Eng.), A.F.R.Ae.S., M.I.Prod.E. (*Assistant Director, Aircraft Production, Ministry of Supply*) : Colonel Clark, of the Machine Tool Trades Association, has seen Mr. Goodinge and arrangements are being made whereby any requirements in respect of machine tools and their development can be specified by the aircraft industry at that level to the Machine Tool Trades Association, and they will then consider the best means of approaching the problem. If the Production Development Branch can lend any assistance to either organisation, we shall be pleased to do so.

Mr. Booth : The National Research Development Association is sponsoring work on machine tools in the Manchester Institute of Technology.

Mr. R. P. Gardner (*Consultant Electrical Engineer, Asquith Machine Tool Corporation Ltd.*) : I can assure the questioner that E.M.I. are working with the machine tool trade. The M.T.T.A. sub-committee has issued a report on electronically controlled machine tools covering the whole field, and my Company is making for an aircraft company, a skin miller which will be tape controlled, though it is not Mr. Puckle's tape. Therefore, something is being done.

Mr. T. A. Waite (*Machine Tool Control Development, Vickers Group Research Establishment, Weybridge*) : Mr. Brown is not quite up-to-date with regard to British-made milling machines. We have one manufactured in this country and propose to fit numerical control to it.

Turning to the Paper, I would congratulate Mr. Puckle upon producing the first comprehensive Paper on machine tools, certainly in this country and probably anywhere else. There will shortly be an even more comprehensive one, but this is the first and Mr. Puckle is to be congratulated upon it. Previous Papers on the subject have rather concentrated on descriptions of particular systems.

Being in intimate contact with aircraft machining processes, I would not agree with the general description given of the way machining is done in the aircraft industry at the moment. The operator does not turn a handle, do a bit of thinking and then turn another handle. The bulk of machining is done by copy milling from templates. But as yet the speed and accuracy of these machines are superior to any that I have seen electronically controlled.

The aircraft production engineer has a very acute machining problem. He may have to remove up to 90% of the material from his billet. Therefore, he is acutely interested in pounds per h.p. per minute. To achieve this, he is prepared to sacrifice accuracy to some extent, but he is not prepared to sacrifice surface finish, for reasons given by Major Teed in his Paper. So the critical specification for him is not the accuracy in so many thousandths of an inch, but the accuracy of so many thousandths per unit of cutter movement, and that is a different thing.

Perhaps I could have some comments on the following. By manually operating a copying machine, we can get up to a speed of 15 ft. per minute, cutter feed rate. I do not think this would be possible with an electronically controlled machine tool, because of the facility which the operator has for anticipating the movement of his cutter. Therefore, it may be an economic proposition to use one electronically controlled machine tool to produce the templates and to use the templates on existing machines, automatically or manually controlled, which would be cheaper to make and no doubt faster in operation.

You mentioned that it was a pity that there was not in operation a machine which translates a picture

of a drawing into a machined workpiece. In my Company there is such a machine in operation.

You also mentioned cutter compensation, which I believe is a feature of your machine. It is also possible to do it on a digital machine, and we hope shortly to prove that point.

There is a technical detail on which I should like Mr. Booth's comments.

In Mr. Puckle's Paper (page 8 of the preprint) there is quoted an informational tolerance of 0.001", a cutter feed rate of 50" per minute, and a cutter radius of ½". That would imply a machine working at about 1" per second. To control this to 0.001", you would have to have a motor which is capable of responding in periods of the order of a millisecond. I do not know of any such motor, and should be interested to know what you have done in this direction.

I thank Mr. Puckle for his Paper. It has given us a comprehensive review of the present state of machine tool development.

Mr. Puckle : I am, of course, fully aware of the fact that the repetition work in the aircraft industry is done by copy milling, but the Paper does, unfortunately, suggest that manual operation without masters or templates is used for this purpose. This will be altered in the final form of the Paper, and I am grateful to Mr. Waite for pointing out the lack of clarity.

I do not fully understand the question about informational tolerances and time constants. If one ignores machine tool errors, the tool will follow a correct straight line path though there will be a time lag, however small. Furthermore, there is no reason why one dimension should not be highly accurate if this dimension is constant, even though a very high feed rate is used in another dimension.

Mr. Booth : You have referred to a speed of 15 ft. per minute. The Giddings and Lewis American machine is operated at 100" per minute, and the Cincinnati skin millers are expected to operate at up to 120" per minute under control.

As to compensation, I imagine that is a question of the size of the computer that you feel you can afford to have on the spot. A large computer could be used immediately adjacent to the machine tool and could carry out cutter radius compensation, but it is likely not to be economical. Most digitally controlled machine tools have used a large computer, and it has been felt necessary to move it to a central place and to share it with other machine tools.

The point about copying drawings is rather a question of what you mean by " drawings ". There certainly are machines which can accurately reproduce drawings. There is a Swiss machine which copies drawings. But that is not using the sort of drawing which we have in mind in this case. What Mr. Puckle means is that there is no means of directly translating the information, in the form in which it is first conceived, into our machine. There always has to be some human processing to the entry to the numerical machine, and that is programming in its widest form. One of the advances that we must make is to reduce the amount of programming well below its present figure. I do not think it is any answer to the problem to produce an extremely accurate copy of the drawing, as the Swiss machine does, because of the labour involved in producing the accurate drawing.

Mr. Waite : In the case of the machine which I have mentioned, it is not necessary to have a specially designed computer. For a simple design, it is possible to use any suitable computer to produce the information for you. If the organisation with which you are associated has one, it would not be necessary to have a specially designed computer.

Mr. Booth : There must be a certain amount of special design associated with it. I do not know of any existing computer which could deal direct with any existing transducer.

Mr. Puckle : My words were " could be arranged to do this work ". My answer is that you might have to add a small amount to it to do it.

With regard to the business of copying drawings, the expensive and accurate work of making the special drawing is a form of programming for the machine.

Mr. R. E. Mills (*Specialist Designer* (*Mechanical*), *A. V. Roe & Co. Ltd.*) : It appears from the discussion that even at this late stage there is still some doubt as to the value of machine tools controlled in this way.

I wish to put a question which I have asked on several occasions. I think there is only one case to which this method of machining can usefully be put, and I should like to have Mr. Puckle's opinion on it. Whatever the shape, be it in two or three dimensions, I should imagine that the cutter can cut at optimum speed all the time. This appears to me to be a most refined method of machining where machining stresses are — I will not say " cut out " — kept constant throughout the whole of the manufacture of the component.

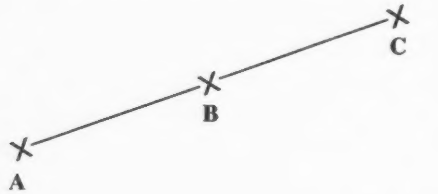
I should like to hear Mr. Puckle's views on whether this machining can be considered as I have suggested, which, in spite of all the other doubtful points, is worth something — bearing in mind Major Teed's Paper.

Mr. Puckle : It is not possible to keep the speed of cutting constant. When one gets to a straight part, one can in general run more rapidly than one can round a curve. One then has to catch up the velocity at the end of a curve where it joins a straight, since sudden changes in velocity should obviously be avoided. That is to say, you may have to alter the velocity of feed as you approach a bend, or come from a bend on to a straight.

Mr. Mills : You would do that in normal circumstances. In fact, you might actually stop.

Mr. Puckle : Yes. We have developed something called a parabolic start and parabolic stop.

Mr. Booth : If with a simple form of E.M.I. control you assume that the time taken to go from A to B is the same as that from B to C, but put B other than in the middle, the speed can be varied



during the interval. For instance, if the distances AB, BC are in the ratio of 3 : 1, you can make the machine move under a constant deceleration from A to C and stop at C. This is a useful feature when approaching a corner. There can be any desired ratio of initial to final velocity by suitable choice of the position of the point B. In the case of the skin-miller discussed in the Paper, there is a programmed choice of feed rates.

Mr. J. O. Mayer (*Aircraft Production Development, Ministry of Supply*) : A contributor has referred to the possible economies to be achieved by equipping several machines, or one, with tape control. I thought it was generally intended that one would have a master tape-controlled machine, which could cut master forms fairly accurately, although perhaps slowly, and copying machines which could run at the desired higher speeds.

With digital computers, it is possible to translate polar information to cartesian and *vice versa*. If we have an analogue-equipped machine tool, are we tied to one form of drawing office information, or can we convert from one to the other and, if so, how ?

Mr. Booth : I should have thought it was largely a question of the way in which the machine was constructed. If it is a machine with more than the essential free axis — in other words, you can rotate as well as go acrosswise — then it will naturally be possible to put information for any of the axes that you have.

If, however, the information is presented in a form different from the way in which the machine is constructed, for instance, polar instead of cartesian, then a conversion may take place, either by conventional techniques of manual computing, or by the use of a digital computer. Generally speaking, the use of this computer is independent of the type of control used on the machine tool, and can as easily precede an analogue control system as a digital one. It would be possible to design either type of control system to accept alternative types of input directly, but to the best of my knowledge this has not so far been done. The nearest approach is perhaps certain American systems, where a general purpose computer is an invariable accompaniment to the system, and where this conversion can easily be done if the computer is large enough.

A much more important question than whether information is presented in polar of cartesian form is the way in which the shapes are specified, whether you must specify blend points or merely that you want a $\frac{1}{2}''$ radius to blend between two straight lines, which latter seems to me desirable to save programming time.

I accept what has been said about extremely complex cases in which, although you may make a three-dimensional model, under numerical control, you still have a very considerable waste of time in the setting up of the various templates. I have seen some incredibly complex Cincinnati machines in which there are 100 templates to fix on the machine, and the time taken to put them on is much greater than the operating time, and I do not think that is an economic process. In more reasonable cases — which means the majority — it is right to produce templates first, and so it may perhaps be in the case of turbine blades.

Mr. S. W. Potter, A.M.I.Mech.E., A.M.I.Prod.E. (*Development Engineer/Works, Royal Aircraft Establishment*) : I was surprised to hear the lecturer place the possibility of adherence to more kinematic principles of machine tool design last on his list. I should have thought that this was a fundamental first requirement to obtain the maximum accuracy from any known reproduction system.

Along with some aircraft firms, we have the problem of producing highly accurate aircraft models for aerodynamic testing, and we hope eventually to produce a machine tool which is capable of fully programmed universal movement in three linear dimensions and possibly three angular dimensions, but this will take some time to develop, possibly four or five years. We know there will be a gain in producing a machine of that type. We are out for fundamental accuracy, and the systems of control known at the moment fall short of the ideal around which to develop a machine tool of that complexity. However, as an interim measure, we are taking advantage of an English machine tool which is capable of *positioning*, using punched card control, to this degree of accuracy. I say "positioning" as distinct from "continuously moving" because the reaction of the machine tool during cutting is fundamentally different.

We are producing models by machining a series of facets tangential to the required profile, for which the machine itself is set to this extreme accuracy. To aid this machining of models, which includes milling the facets on an existing jig boring machine, we shall have a similar machine converted to programmed positioning on three axés whereas the present type controls only two axés.

Reference was made by the lecturer to an inclinable fixture on a skin milling machine which was programme controlled. I should like to know what sort of accuracy of angular setting can be obtained on this

fixture. The degree of accuracy is interesting because we have a similar problem in the precise angular presentation of workpiece to cutter, and so far we have considered a linear scan well displaced from the centre, rather than adhering to circular scale setting, as being essential to obtain the accuracy required.

Mr. Puckle : I am in agreement with Mr. Potter regarding the use of kinematic principles in the design of machine tools, and he is probably correct in suggesting that I have not sufficiently emphasised its importance.

Mr. Booth : I agree with what you say in regard to the application of kinematic principles to machine tool design. I have no idea of the accuracy of the fixture movement on the skin miller. We merely control, not design, the tool.

Mr. G. H. Taylor (*New Development and Process Engineer (Aircraft), English Electric Co. Ltd., Preston*) : I agree that we have to walk before we can run in these matters, and feel there is an urgent need for such control, particularly in the manufacture of wind tunnel models.

In the majority of cases, however, the draughtsman draws the basic shape and leaves the rest to the mould loft, from which models and templates are made, but without dimensions. Dimensions are required for programming.

Would it be possible to produce tapes from the movements carried out by the hydraulic machine, cutting out idle time and saving on computations and programming, and so get us where we want to go a bit faster ?

Mr. Booth : It would be possible — in fact, it has been done by several organisations — to record the movements of a machine either under copying or manual control. It has been done by General Electric and others, and also by Hewittic in France. But I should have thought that the essential computation had been done in the original model.

Mr. Taylor : What about starting off from the mould loft ? We should want ordinates.

Mr. Booth : Given a series of ordinates, that is basically what is needed for programming.

Mr. Taylor : But it would mean working out a very much greater range of them, and there would be millions of calculations.

Mr. Booth : Fundamentally, that additional process is one of interpolation which it should be the job of the control system to do. Any control system, if given a long straight line to do, automatically introduces a long line of points all the way along, there being vast numbers of intermediate points. The same process is undertaken round curves. As long as enough points are produced to specify what you want, it is the job of the control system to do the additional work, and it should not involve an expert in the drawing office.

Mr. Hollis : The success of the introduction of electronic equipment will depend largely on the presentation made generally. This equipment is costly — generally £15,000 or thereabouts — and while you can lose that sum of money in equipment costing, say, £100,000, it will be difficult to educate people who normally use plant valued between £2,000 and £10,000 to believe that they can afford an additional sum of £15,000, unless you can show that they will get some considerable productive advance resulting from the use of the equipment, or that they will get from the machine tool greater utility and versatility, in that it will do jobs that it previously could not do.

We have hammered this matter out with a number of the electronics firms, and we think we have got somewhere towards the answer with regard to specific applications. We feel that electronics will be extremely useful in a case calling for a high degree of repetition. Yet we hear from electronics firms that they have themselves introduced numerical control, simply because of the great number of different problems with which they have to contend and that the versatility of the equipment justifies its cost. I wonder what views Mr. Puckle or Mr. Booth have about this.

Mr. Puckle : I think these machines have one very great advantage in respect of tooling. In relation to turning out small quantities for making such things as templates and jigs, they have the advantage that they permit you to make rapid alterations. You can make another cam extremely quickly. One cam shown in the Paper took 45 minutes to make, compared with something like three weeks. That represents a value which you just cannot afford to be without. It is a case not of whether you can afford it, but of whether you can afford not to have it.

When it comes to large quantity production, I think it depends on the type of industry you are in. If you are in the aircraft industry, particularly the civil aircraft industry, I think that what you call "large quantities" are probably within the capability of the machine and the consistency obtained in repetition is of the greatest value. If, however, you want to turn out quantities of the 100,000 order, I would not suggest that you should try to do it with a numerically controlled machine. I suggest that you might make a model of it from your drawing with a numerically controlled machine, and then put the model on to a copying machine to make it in quantity.

Another great advantage lies in its use in the model shop attached to a Research or Development Department. It becomes easy to obtain modified parts much more rapidly when a numerically controlled machine tool is available, and so the likelihood of "bugs" appearing in the finished product is generally reduced. This should appeal greatly to the production engineer, because the value of the time and

trouble saved can be much greater than the cost of adding numerical control. Moreover, the time saved in research and development means that production can start earlier.

Mr. L. J. Bolton (*Production Superintendent (Hydraulics), Sperry Gyroscope Company Limited*): In regard to cutter compensation, it has been said that one of the difficulties is that, due to the swarf and the coolant, it is difficult to take a measurement of any cutter wear. Surely, however, it should be possible to measure the deviations of the form you have just cut from the desired line, by either optical or mechanical means, and feed that deviation back into the system and so make an allowance and correction for it. Has that been done ?

Mr. Booth : Yes, in principle. One factor which arises is that some of the errors of the work are not necessarily repetitive. However, so far as the cutter itself is concerned, perhaps there it could be done. The worthwhileness of it depends on whether the errors that you want to correct are due to permanent effects such as wear of the cutter, or to factors such as strain in the machine, which will be different on a second cut, because the cutter load is much less.

Mr. L. G. Burnard (*Chief Development Engineer, Vickers-Armstrongs (Aircraft) Ltd.*): I should like to revert to an earlier question about the use of drawings and the possibility of a machine which would be able to read a drawing.

Would it not be possible, with the development of this technique in the future, to dispense entirely with drawings ? If a part such as a pipe or a wing contour can be described mathematically or numerically, it would be possible for the draughtsman or someone at the draughtsman's desk to punch a card containing this numerical information and, possibly, information about the number of parts to be made, and pass it to the machine shop, so that we might get a part or parts from the shop without the intermediate planning, ratefixing, work office, production control, and so on. There is a possibility of this happening in the future. It may be that we shall then see our production control work done by a computer of some sort. There are millions of bits of information which could go into the memory or store of a standard computer so that, with certain parameters, it could give you immediately the information you want about the state of production in the shop.

It is said in the Paper that one of the advantages of the analogue system is that if, for any reason, the machine is stopped, it will return to the position when next switched on, the voltage analogue having been determined. Surely that can also be done today with the digital system ? New binary coded scales are available which have unique positions for every increment that you wish to put along the machine tool slide. Thus, if there is a unique position, the machine upon being switched on, will return to that position. Is that true ?

Mr. Booth : Yes, that is already dealt with. I think the statement in the Paper is true. The digital systems in this country and America have been incremental systems, but in principle it is certainly true, and I know of a rotary form of what you describe.

I would suggest that very often a qualitative drawing will be wanted, because most people have pictorial minds long before, and to a much greater extent than, they have numerical minds. I am sure that qualitative drawings will continue to be necessary.

Mr. Burnard : I meant that the drawing could be done in the shops because there was a numerically controlled inspectorate.

Mr. Booth : There is still the pictorial case to be considered.

Mr. Puckle : Mr. Burnard is quite right in saying that a computer can be used for Shop Planning Control purposes, but that lies outside the scope of my Paper.

The **Chairman :** It is a pity that we do not have more time for discussion. It has been most stimulating. We now have plenty to think about while our companies save up enough money to purchase numerically controlled machine tools.

I should like to return to a point in Mr. Puckle's Paper. He mentioned that an aluminium part was prepared in half a day and machined in 14 minutes, but it took 12 hours to inspect. I suggest that a numerically controlled checking apparatus be devised as quickly as possible, to obviate having to have a horde of inspectors checking the things turned out with the machine.

The advantage of the equipment must be apparent, particularly in the accurate production of complicated machine parts in expensive materials which we are now having to face in the new projects — the very high tensile steels, titanium and similar materials.

I thank Mr. Puckle on behalf of the Southampton Section of the Institution of Production Engineers for his excellent Paper.

The vote of thanks was carried by acclamation.

Mr. Puckle : The Chairman has remarked on an aluminium part made in 14 minutes which took 12 hours to inspect. I would draw his attention to the fact that this statement appears in my extract from the Paper read by Mr. Wood in Cincinnati. We are in agreement that an electronic inspecting device would have great value for many purposes. On the other hand, perhaps I might say that once the first part has been made and checked, there should not be any need to check future ones made from the same tape !

WELDING DISTORTION PROBLEMS ENCOUNTERED IN THE GAS TURBINE INDUSTRY

by S. A. ONIONS, Grad.I.Prod.E., Grad.Inst.W.

THE advent of the gas turbine has introduced to the aircraft industry many problems not encountered during the manufacture of reciprocating engines.

The design of the engine is such that large complicated components are required which are able to resist high temperature, high stress and have a good strength to weight ratio.

These conditions have necessitated the use of heat resisting high strength steels and also the use of very thin-walled components.

To produce these thin sections from a casting requires many hours of machining and, in some cases, the complicated shapes preclude normal casting methods altogether.

Because of this, fabrication by welding of sheet materials is playing an ever increasing part in the production of gas turbines.

Fabricated assemblies are now used in the very heart of the engine and a very high standard of precision is required.

One of the great problems governing the successful manufacture of welded assemblies is weld distortion, and in this essay it is proposed briefly to examine its causes and the economic and technical difficulties involved in its correction.

Definition of Weld Distortion

Weld distortion is the change in shape, temporary or permanent, of the parts on assembly as a result of the operation of welding.

Cause of Weld Distortion

In order to understand the cause of distortion, it is necessary to consider the basic principle that all metals expand, to a greater or lesser degree, according to their co-efficient of expansion when subjected to a temperature rise.

If the heat applied is uniform throughout the volume of the metal, the expansion will be uniform in every direction and if cooling is equally uniform, then the metal will return to its original dimensions. If, however, the metal is restrained from expanding or contracting, distortion will take place.

A simple illustration of this is to hold a bar between vice jaws (Fig. 1). On the application of heat to the bar, the expansion along its axis will be restrained and, therefore, greater expansion will take place on the diameter of the bar. As the bar cools, the contraction will not be restrained and the result will be a permanent deformation of the bar to reduce its length and increase its diameter.

If we now consider the application of local heat to one particular part of the bar — the heated mass will try to expand in all directions, but its expansion will be restrained by the surrounding cold metal. The restraint may be likened to the jaws of the vice in the case of the uniformly heated bar. As the surrounding cold metal is restraining the expansion in all directions except on the surface to which the heat is being applied, the displacement of metal will occur over that area. When the area starts to cool and contract, a certain amount of the displacement remains permanent, causing an uneven contraction throughout the area. The result is distortion.

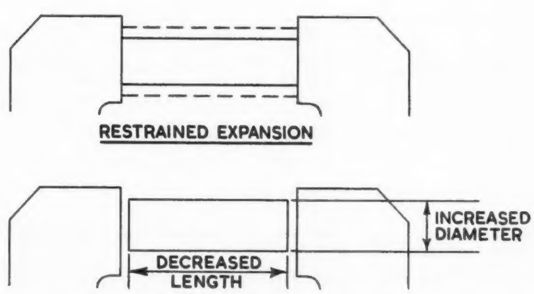


FIG. 1

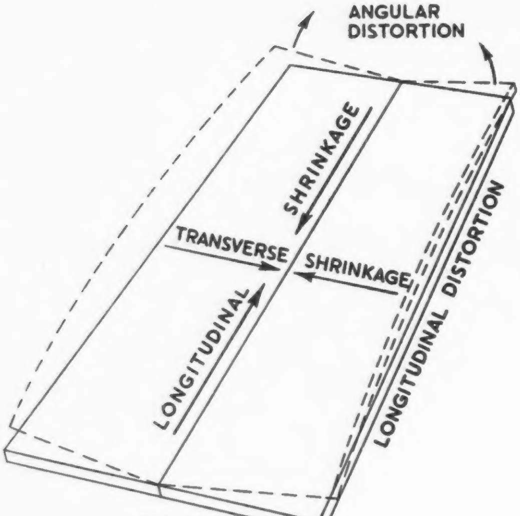


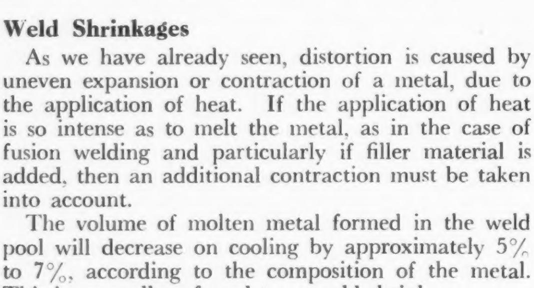
FIG. 2

Any welding process necessitates the application of intense heat to a local zone of the components under fabrication. This means that whenever a weld is made, the basic cause of distortion is always present. It follows that weld distortion, although it may be minimised or accommodated, cannot be prevented.

Weld Shrinkages

As we have already seen, distortion is caused by uneven expansion or contraction of a metal, due to the application of heat. If the application of heat is so intense as to melt the metal, as in the case of fusion welding and particularly if filler material is added, then an additional contraction must be taken into account.

The volume of molten metal formed in the weld pool will decrease on cooling by approximately 5% to 7%, according to the composition of the metal. This is generally referred to as weld shrinkage.



A. LOSS DUE TO TRANSVERSE SHRINKAGE

B. LOSS DUE TO TRANSVERSE SHRINKAGE AND ANGULAR DISTORTION (θ)

FIG. 3

The Practical Aspect of Welding Distortion and Shrinkage

Let us now consider the principles of distortion and weld shrinkage as applied to simple welded joints.

These joints may be divided into three types :-

1. Butt joint.
2. T or fillet joint
3. Lap joint.

1. *Butt Joints*

Firstly we will examine the shrinkages and resulting distortion which take place in a welded butt joint (Fig. 2).

The shrinkage in the joint occurs in three directions, namely, at right angles to the weld, parallel to the axis of the weld and vertically through the weld.

The latter is of little consequence in most thin gauge welding applications and, therefore, it is not proposed to discuss it further.

Taking the simplest example of butt welding together two plates, shrinkage at right angles to the weld will cause a decrease in the overall width of the plates. The amount of shrinkage that takes place varies considerably with the degree of restraint applied to the plates, but the primary factor affecting the amount of shrinkage is the size of the cross-sectional area of the weld bead. The larger the weld bead, the greater is the shrinkage. A very approximate value of this weld shrinkage is $\frac{1}{4}''$ per square inch of weld.

When considering this transverse shrinkage, it is also necessary to take into account the angular distortion caused by the fact that there is a shorter length of contracting metal at the root than at the face of the weld. It will be seen from the diagram (Fig. 3) that the total loss of width is made up of a combination of shrinkage in the horizontal plane, plus the angular distortion.

Shrinkage parallel to the weld tends to reduce the overall length and this subjects the surrounding cold metal to compressive stress. If the metal is not sufficiently robust to resist this compressive stress, then bowing will take place in the horizontal plane.

It is reasonable to assume that shrinkage parallel to the weld is proportional to its length, so that, assuming a constant weld bead, a weld 4″ long will tend to have twice the parallel shrinkage of a weld 2″ long, whereas both will have the same shrinkage at right angles to the weld.

2. *T or Fillet Joints*

In the case of T joints (Fig. 4) the angular distortion resulting from the unequal contraction through the weld bead is the most important, but it must not be overlooked that weld shrinkage parallel to the weld is also present.

Another factor which must be considered in the case of T joints is the distortion due to expansion (Fig. 5). When the heat is applied to make the weld, the temperature on the reverse side of the plate will be raised at least to red heat. As this

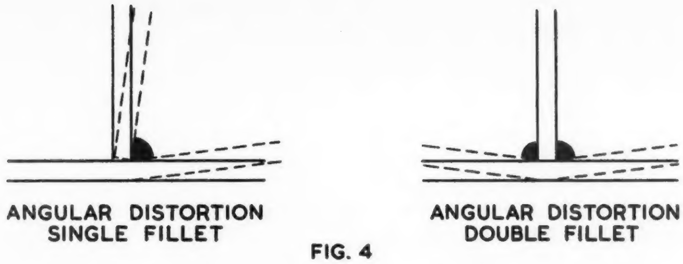


FIG. 4

heated layer attempts to expand, it is restrained by the surrounding cold metal and, therefore, a permanent local set or bulge is caused. It will be seen, therefore, that although one end of the T-piece was originally flush with the face of the plate, its final length in relationship to the mating face will be reduced. It will be shown later how this distortion can have a very adverse effect in certain applications.

3. *Lap Joints*

The shrinkages encountered in lap joints are similar to those encountered in T-joints. Shrinkage across the weld pool causes angular distortion and this in turn causes the lapped faces to part. Parallel shrinkage is also present and so is the bulging effect on the underside of the plate.

When considering lap joints, it must be noted that resistance welding by spot, stitch or seam methods are all lap welding applications and although the shrinkages obtained by this mode of welding are less than for fusion welding, they do in fact take place.

Restoring of Accuracy After Welding
Butt Welded Assemblies

Gas turbine assemblies contain fusion welded butt joints in two main categories, namely, longitudinal and circumferential.

Typical applications of longitudinal welds are the welding of rolled cones and cylinders and drop stamped segmental pressings.

The weld shrinkage and distortion associated with

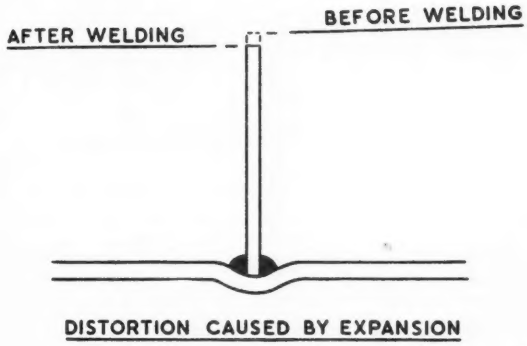


FIG. 5

butt welds makes it impossible to fabricate these items to give a true component without further attention. Exactly how much attention should be given to the correction of the component depends upon its function in the assembly, and to the degree of accuracy of its fit to mating parts.

As an example, rolled cylinders or cones which are strengthened by stiffening rings require a high degree of accuracy in size and form (Fig. 6).

The stiffening rings are spot or seam welded to the casing and a very good fit is required to produce high quality resistance welds. The casing must be sized to within + .010″ on diameter and the ring to within –.010″ on diameter, giving a maximum gap of .020″.

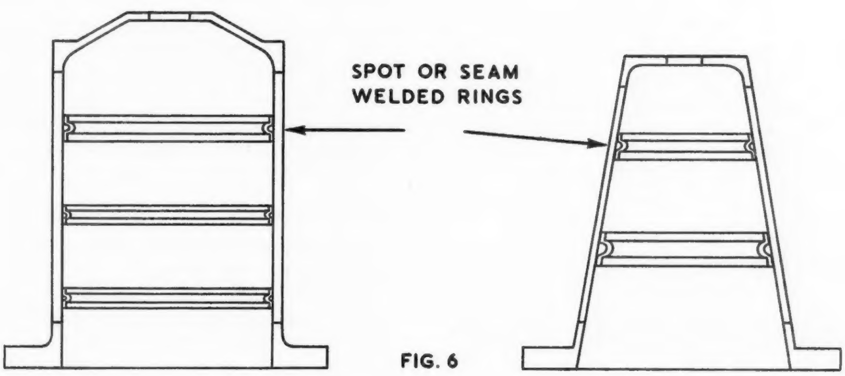


FIG. 6

FIG. 7A

STRETCH OR SHRINK SIZING MANDREL

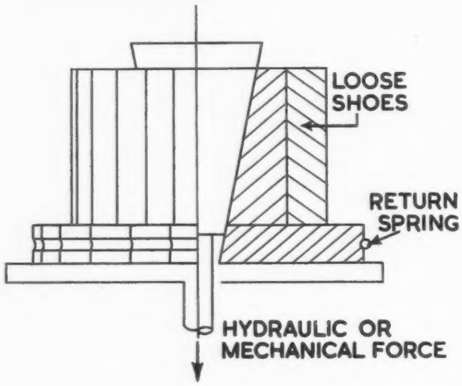
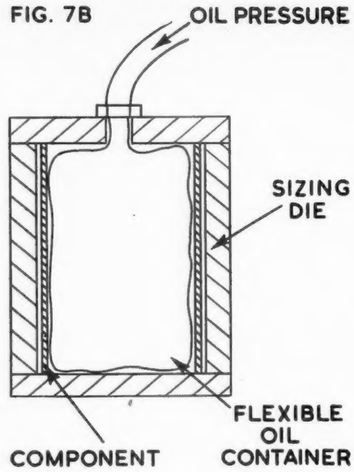


FIG. 7B



There are a number of ways of obtaining the desired result, but each follows the same basic principle, that is, to cause a permanent set in the material by expanding it beyond its elastic limit.

The most common method in use, is known as "Stretch Sizing" (Fig. 7a). With this method the component is loaded on a segmented die which is expanded by hydraulic or mechanical means and thereby stretches the material beyond its elastic limit.

Another method is to expand the component by means of heat treatment and allow it to cool on a collapsible mandrel. In this case the shrinkage stress is relied upon to expand the material. This operation is known as " Shrink Sizing " (also Fig. 7a).

A third method, known as "Hyde Sizing" (Fig. 7b), is performed by loading the component into a die and expanding it by fluid pressure to meet the walls of the die.

Advantages and Disadvantages

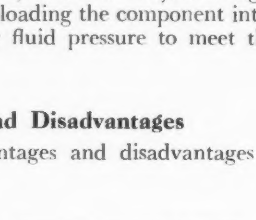
Certain advantages and disadvantages exist with all three methods, from both a technical and economic aspect.

Stretch sizing requires a special purpose machine or a hydraulic press to supply the power needed to actuate the conical ram. The initial capital outlay for either plant is high, but it must also be noted that the expanding dies can be used to size a large range of diameters and forms by the addition of appropriate shoes. The operation is a very short cycle and a fairly accurate size can be maintained.

Shrink sizing requires a comparatively small capital outlay and the basic mandrel is very similar to that used for expanding, except that the conical ram is used only to lock the segments in position while shrinking takes place and is withdrawn to allow the segments to collapse. The disadvantage of this method is that considerable heat treatment capacity is required and the cycle time for heating and cooling is of fairly long duration.

Hyde sizing will produce components of greater accuracy than the other two methods, because the die is either in one piece or split only in one plane. This means that no local flats occur on the component due to using segmented dies, as in the other methods.

The technical difficulty associated with this method is the making of a die to withstand the very high pressures, which can be readily dismantled to remove the component. The high cost of making such a die also limits the use of this method to components requiring extreme accuracy.



DISTORTION CAUSED BY CIRCUMFERENTIAL WELDING

FIG. 8

Circumferential Butt Welds

Circumferential butt joints occur mainly where machined flanges are welded to a sheet metal casing (Fig. 8). The shrinkage occurring parallel to the weld tends to reduce the diameter of the assembly at the weld line, thereby causing the flange and casing to distort.

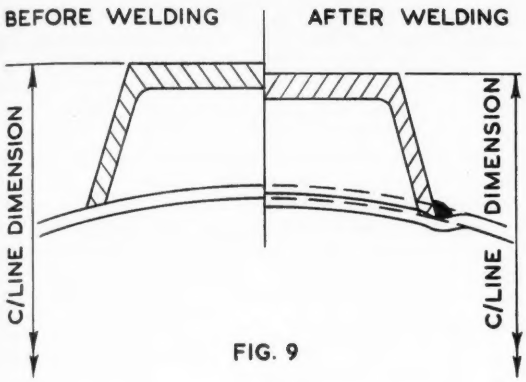


FIG. 9

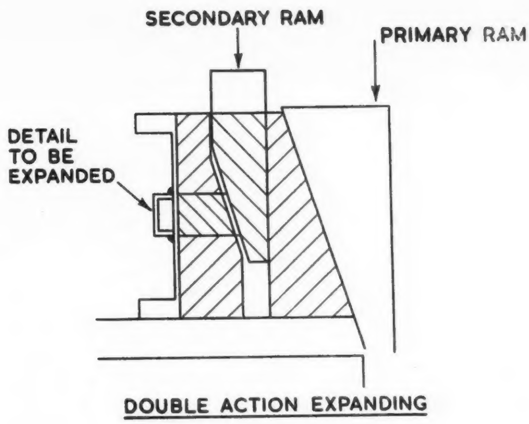


FIG. 10

The angular distortion in the flange faces is quite often corrected by subsequent machining of the flange profile, an appropriate machining allowance being provided. Whether this apparently simple method of correction is a sound economic proposition is debatable.

On large assemblies of, say, 40" diameter or more, as much as .100" of metal may be left on a face to ensure "clean up" on machining. The cost of removing this metal is much higher than may appear at first glance.

The assembly not being of a robust nature does not lend itself to heavy cutting, therefore machining takes a considerable amount of time. The size of machine used and the class of labour employed makes machining hours a most expensive item.

By expanding these welds locally on each side of the weld line, to restore them at least partially to their true plane, it will be possible to reduce the amount of metal required to true up, thereby reducing machining time.

It will be seen that the stretch or shrink sizing applications can be used for sizing the sheet metal casing before welding flanges and sizing the sub-assembly of the casing and flanges.

Preventing distortion during welding of longitudinal or circumferential butt welds is not a practical proposition. In the case of rolled cylinders and cones, a true form is not obtained from rolling and, therefore, even if weld distortion could be eliminated a true formed component would not be obtainable.

Preventing angular distortion by heavy clamping on flanges does reduce distortion to a certain degree, but the weld is in a state of tension and although the flange face may be held flat in the jig, it will distort as soon as the clamping pressure is removed and will further distort on being heat treated. Very severe restraint of the welded parts may also lead to weld cracking. It is, therefore, considered better to correct the distortion after the assembly has been heat-treated to remove the hardened zones from the weld bead and heat affected zone.

Fillet Welded Assemblies

Fillet joints are used in a variety of applications on gas turbine assemblies, but they are mainly encountered in welding precision cast or machined details around main casings, and in welding correcting vanes between inner and outer casings.

The shrinkages, bulging, and angular distortion associated with fillet welds give rise to complex distortions, but the resultant effect is almost always for the detail component to move towards the centre of the casing to which it is being welded (Fig. 9).

Details welded to a single casing assembly (Fig. 10) can be expanded to their correct centreline dimension, but double action expanding equipment is required. One set of segments must be expanded to hold the general form of the casing, while a second set expand locally at the detail position.

It is also possible locally to expand the casing before welding the details, and the advantage of this would be that the completed weld would not be subject to further cold working, therefore cracking would be less likely.

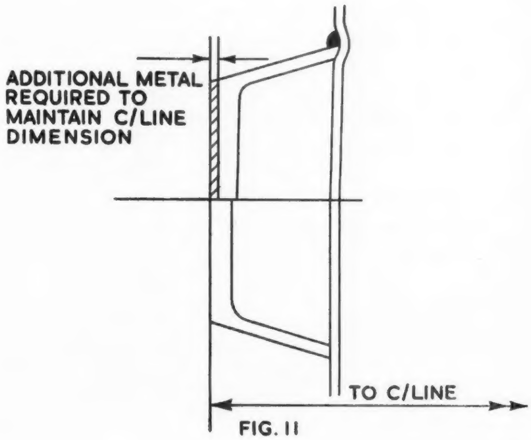


FIG. 11

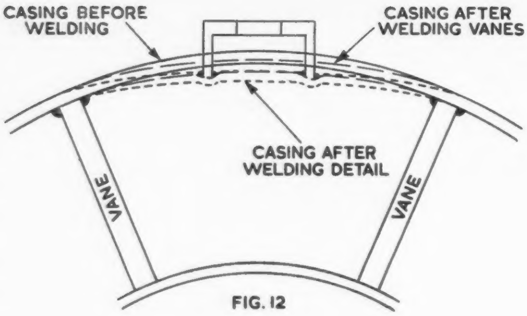


FIG. 12

So far as is known, double action expanding has not been used to any great extent due to the very high cost and the technical difficulties of producing suitable equipment.

The method now in common use for accommodating this distortion, is to allow extra metal on the mating edge of the component to offset the amount lost on centreline dimension due to distortion. Although this method is simple and effective, its great disadvantage is that it impairs the strength to weight ratio (Fig. 11).

Distortion can be reduced during welding by backing the underside of the welded detail with a copper faced jack, but again this may increase the amount of cracking in the weld.

In the case of assemblies having two casings joined by a series of vanes, distortion from filler welds becomes even more complex. The welding of the vanes will cause the circular casing to take the form of a polygon having as many sides as there are vanes. This means that the diameter of the casing is reduced by the flat between the vanes. If it is now required to weld a detail between the vane positions, it will be seen that a certain loss on centreline dimension has already occurred before welding of the detail takes place. The welding of the detail will cause further loss and a combination of these losses can assume large proportions and may result in a reduction of as much as .150″ on centreline dimension (Fig. 12).

It seems that little can be done to correct distortion caused by the welding of vanes. Expanding is impracticable, as the existence of the inner casing prevents expanding of the outer casing, while the inner casing is usually of unsuitable design for expanding. It therefore appears that the only line of action is to fabricate the details to the outer casing, and maintain their centreline dimensions on the plus side by either pre-expanding or expanding after welding, in order to accommodate the vane distortion.

The problems encountered in local fillet welding distortion are very difficult to correct, and much work remains to be carried out before a satisfactory solution is reached.

Lap Welded Assemblies

Lap welds have their greatest application in the resistance welding techniques of spot, stitch and seam welding.

The amount of distortion associated with these techniques is less than that produced by fusion welding. The reasons for this are that the heat imput is of very short cycle, is very local and is more accurately controlled.

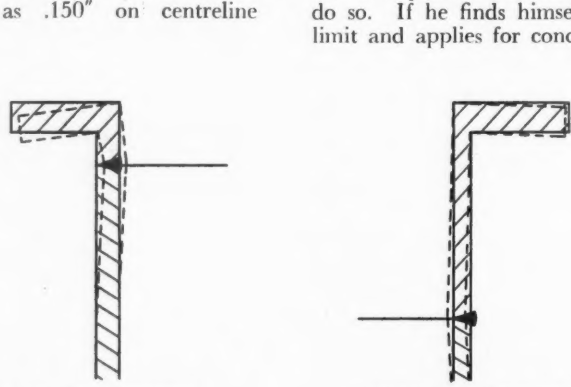
Resistance welds by these techniques are either longitudinal or circumferential and the methods used to correct distortion are similar to those already described for fusion welding.

Design of Welded Assemblies

The production of welded assemblies would be very much simplified if the designer would give more indication as to which are the important dimensions on an assembly.

The remark that appears on most drawings stating that all dimensions, unless otherwise stated, should be within $\pm$ .010″ should, in my opinion, be removed from fabricated assembly drawings and a wider tolerance instituted.

The Planning Engineer endeavours to maintain all dimensions within the $\pm$ .010″ limit, because he is not in a position to know whether it is essential to do so. If he finds himself unable to maintain this limit and applies for concession, he may find that a



ANGULAR DISTORTION CAUSED BY CLOSE PROXIMITY OF WELD TO FLANGE

ANGULAR DISTORTION REDUCED BY RE-POSITIONING WELD

FIG. 13

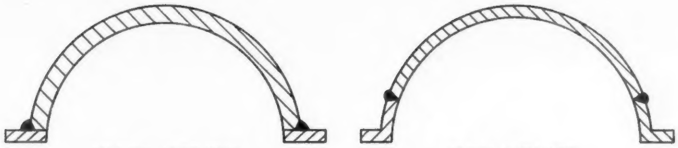


FIG. 14

particular detail is coupled to a flexible pipe, or is only a drain boss, and its position may be satisfactory within $\pm$ .050".

Some American aircraft fabrication drawings give tolerances of $\frac{3}{16}$", a limit I have never seen on British drawings.

If the designer would indicate more fully which are the important dimensions and give maximum tolerance on the relatively unimportant ones, then the Planning Engineer could concentrate on maintaining the important and not waste time and money on the unimportant.

Designers can help minimise distortion by the positioning of welds, a simple example of this being the amount of angular distortion caused by the position of circumferential welds (Fig. 13).

Fillet welds should be avoided where possible and butt or lap welds used instead. A simple example of the use of butt welding instead of fillet welding is shown in Fig. 14. This application shows the re-positioning of a weld on a compressor casing half section.

Conclusions

This essay has attempted to emphasise the need for production, welding and design engineers in the gas turbine industry to continue increasingly in their endeavour to study and understand the complex subject of weld distortion.

The reduction of weld distortion is essential for three reasons :-

1. To reduce the amount of machining required from the economic viewpoint.
2. To reduce the amount of machining, thereby reducing the stress set up by machining.
3. To avoid impairing the strength to weight ratio by adding additional material which is not essential to the function of the assembly.

The production engineer must endeavour to produce a welded assembly as close as possible to a fully machined part, consistent with the economic considerations.

AIRCRAFT PRODUCTION CONFERENCE — OPENING ADDRESSES

(concluded from page 144)

It was often said, Mr. Maudling went on, that there were too many individual firms in the aircraft industry. That might well be so. Obviously, there would be great advantages in the development of larger and stronger individual units. But he thought it would be a very foolish man who attempted to lay down the number of firms that there ought to be and what those firms should do.

It was not possible to make progress in these matters by compulsion. It must be rather a natural progression. It was all very well for some ingenious planners and theoreticians to say : " Let us have bigger firms. Put two firms together and get a super-firm ", but he would like to see them putting two chief designers together and getting one super-designer!

He believed that the Government's job was to do all it could to see that the pattern of demand placed on the industry was such as to encourage the growth of the sort of units or companies or associations which would be enabled best to use national resources, in materials and human brain-power, to compete with giants like America and Russia in the future.

It all came back, in Britain, to brain-power, to engineering manpower, to designers, to draughtsmen, and to development and production engineers. If those assets were wasted, it would indeed be a very great default. Anything that the members of the Institution of Production Engineers could do to expand the scientific and technical resources of this country, which were so important to the future of Britain, would be of lasting benefit to all the people who live in this island.

THE DELFT CONFERENCE

The following comments on the Report of the Delft Conference on the teaching of production engineering at University level (published in the December, 1956, issue of the Journal) have been received from Mr. W. G. Ainslie, M.I.Prod.E., Lecturer in the Department of Engineering Production at Birmingham University.

Mr. Ainslie serves on both the Education and Research Committees of the Institution.

I FEEL we must guard against tacit transfer of authority and I would question whether the universities have proved their efficiency in *this* field of education to be so good as in other fields, and whether their judgment is justified on the following matters in the Report of the Delft Conference.*

On page 4 of the Report (Institution of Production Engineers Journal, December, 1956, page 718), regarding the comments on the Institution of Production Engineers' proposed revised syllabus, they ignore the fact that the examination is intended for external candidates as well as college students. While the latter could no doubt be subject to supervision in the preparing of the thesis or disquisition, the former could not, and their theses would not, carry an absolute guarantee of original work or investigation. Marking and assessing also present grave difficulties and guidance on choice of topics, methods of treatment and background subjects would be necessary which, in effect, would become a syllabus similar to the proposed scheme.

Page 4, *paragraph* 9 (Institution of Production Engineers Journal, December, 1956, page 718, paragraph 9).

After agreeing wholeheartedly that "the universities endeavour to train a well selected element of the population in the discipline of pure thought plus the use of the imagination ", I am at a loss to see why this can *only* be done by " physical science, economics and psychology ". Is there no deep thought required in the design of machine tools, in investigating the theory of cutting metals, in the study of the theory of rolling, or in the analysis of the kinematics of a spiral bevel generator, to mention only four of many complete fields ? The attitude adopted in the paragraph under discussion is similar to that in the Battle of the Classics of last century, when the introduction of physical science into the universities was so bitterly opposed. The classical outlook that Greek and Latin would train the mind, developing its capacity for any future study, closely resembled the theory that it does not much matter *what* a man studies providing he *does* study (even Plato wished to train his " Governors " by giving them 10 years on analytical geometry !). It was here that the physical scientists took issue, observing that there was as much mental development to be derived from the study of Applied Mathematics and Applied Physics as from the Classics, that many more students who disliked language study would be attracted to the sciences and hence actually would develop mentally more rapidly. After graduateship, they then not only had mental capacity *in vacuo* but a certain ability in the theories behind the technologies which put them in front of the arts man. The physical scientist, now accepted, has himself adopted the classic argument against the production technologist ! We maintain that a graduate can have just has much, sometimes more, mental training by studying many aspects of production engineering if they are taught analytically, although very few possess this knowledge to teach it, since they themselves have not been taught that way — a vicious circle !

This again is seen by the enlightening comment on page 6, paragraph 2 (Institution of Production Engineers Journal, December, 1956, page 720, paragraph 2), that " it has been felt that knowledge of manufacturing methods and ability in management would come with experience some time after students left the universities ". This is deplorable and reveals the direct reason for our national plight. How scientific is it to leave to chance the acquirement of a knowledge of running the nation's factories, or to lay the responsibility for the instruction at the door of industry without giving any guidance whatsoever ?

Page 10 (Institution of Production Engineers Journal, December, 1956, page 724, last paragraph).

It is interesting to see that Aachen and Delft each has a Professor in Machine Tool Design, whereas British universities do not acknowledge the need for a Professor in the whole field of production engineering, far less one aspect of it !

Obtainable from the Institution, price 3/6 per copy.

Comment on Recommendations — page 12 (Institution of Production Engineers Journal, December, 1956, page 726).

The general contention that there should be further development of university schemes in Great Britain is, of course, merely stating the obvious, but the necessity for integrating the whole course with Workshop Practice is most welcome, if it is implemented.

The structure suggested is also the 1-3-1 Sandwich Course already in operation in several universities, which does not disturb the traditional academic year. On page 9, (a) 1 (Institution of Production Engineers Journal, December, 1956, page 723), it is stated that a sandwich course of six months in the university and six months in the workshop is "entirely out of the question", but this is neither proven nor acceptable. Indeed, it has been in operation at Glasgow University for many years and has proved very successful, giving *more* time each year to the University for research, more time to employers, and a shorter period of intense study to students ; and the quality of Glasgow University and R.T.C. engineering graduates is world-famous. I advocate an unbiased enquiry into the six-month per year university sandwich course to extend over a period of four years at least.

Further, in the recommendation on page 12, three years' basic engineering study is advocated "if possible with some bias towards the principles of production engineering". This is quite unacceptable and is merely a restatement of orthodox university policy towards production engineering. I suggest that the 1-3-1 system should be arranged as follows :-

1st Year. Basic Engineering Studies.

2nd Year. Basic Production Engineering Studies.

3rd Year. Advanced Production Engineering Studies.

A tentative grouping of subjects could be :-

1st Year

Mathematics
Strength of Materials
Metallurgy
Mechanics of Machines
Mechanics of Fluids
Electrical Technology
Structure of Industry

2nd Year

Mathematics
Strength of Materials
Metallurgy
Mechanics of Machines
Production Technology
Metrology
Tool Design
Economics
Principles of Management

3rd Year

Technical Analysis (= Mathematics and Advanced Mechanics)
Theory of Machine Tools
Advanced Metrology
Tool Design (jigs, fixtures, gauges, cutting tools)
Machine Tool Design
Control Engineering (= or Technology of Automation)
Process Co-ordination (= Plant Layout, Materials Handling, Production Planning, Work Study)
Estimating and Costing
Applied Statistics

For a four-year scheme as suggested earlier, the final year would have greater emphasis on Human Relations, Procedure Analysis, Psychology of Thought, and Management Practice.

There are a few educationists and industrialists who feel that instead of production engineering being a subject of doubtful mental discipline for inclusion in university studies, it is deserving of the position of a faculty, with separate departments having professional chairs in, say, Industrial Metallurgy, Production Technology, Machine Tools, Metrology, Control Engineering, Management, Economics, Accountancy, Statistics, and Work Study. If such faculties existed today, there would not be such an extreme shortage of scientists and technologists of the kind needed by industry and the nation.

W. G. AINSLIE.

SCHOFIELD TRAVEL SCHOLARSHIPS

The Schofield Travel Scholarships are among the most valuable awards open to students in engineering. They offer Graduate members of the Institution of Production Engineers opportunities to obtain experience in other countries. All Graduate members of the Institution are eligible. Application forms may be obtained from the Secretary. Senior executives who have Graduate members in their employ are invited to encourage these employees to apply for the Scholarship.

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

Brief Review of PERA Activities in 1956

Keener competition in overseas markets and rising prices at home stimulated greater and more effective use of all PERA research, information and training services by members generally in 1956. As the Association's income increased substantially during the year, it was possible both to expand existing services and to introduce new services, such as residential training courses for key personnel in industry. Considerable progress was made with the construction of the new research block, which is now nearing completion, as shown in the accompanying photograph.

Research

During the year, general investigations were carried out on machining, stamping, machine tools, impact extrusion, tool grinding, de-burring, cutting fluids, automation, deep drawing, rolling bearings, vibration, grinding, machine tool lubrication, surface finish, etc. Nearly 160 practical investigations were also carried out for individual members. Examples of the results obtained in some of the general investigations are given below.

Large increases in drill life and higher rates of production have been reported by a number of firms applying the results of PERA's researches on the drilling of cast iron, non-ferrous alloys, etc. When drilling cast iron, the most suitable point angle varies with the cutting speed and feed, and the type of cast iron drilled, but laboratory and field tests carried out in conjunction with members have led to the development of suitable point shapes for various conditions.

Preliminary tests indicated that different methods of thinning drill points which are being investigated by PERA may significantly affect performance. Confirmation of these results is being sought in a further series of tests.

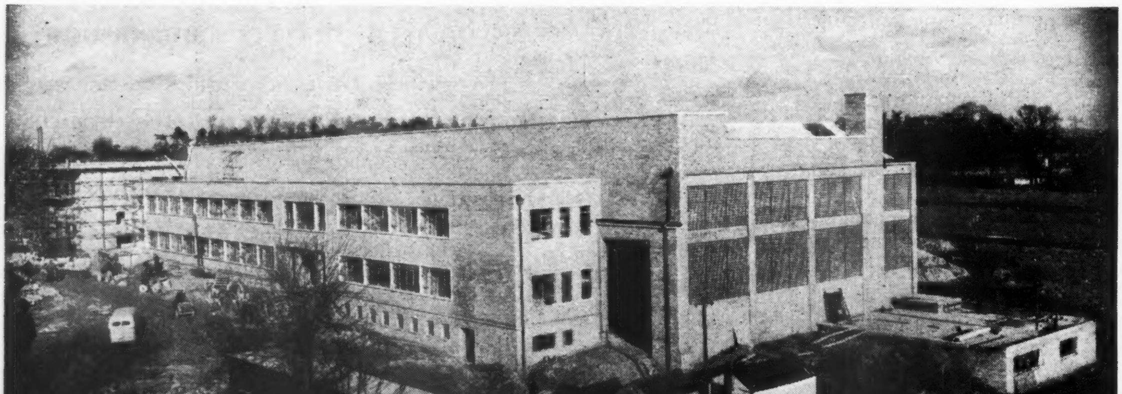
Further field tests were carried out with special oil-less cutting fluids developed by PERA. These fluids are comparable in performance to soluble oils but cost less. The corrosion characteristics of the experimental fluids are similar to those of soluble oil emulsions. Various methods of applying cutting fluids are also being investigated.

Research into a "finish blanking" technique developed at PERA is establishing the most suitable conditions for the production of blanks with smooth crack-free edges without the need for subsequent shaving or machining operations. Significant reductions in production costs have been made by some member-firms applying PERA's recommendations for finish blanking ferrous and non-ferrous materials.

Preliminary results obtained in a deep drawing investigation indicated that substantial increases in depth of draw can be achieved under conditions which differ markedly from conventional practice.

An investigation into the accuracy of assessing surface finishes by means of plastic replicas showed that substantial errors could arise, and indicated the conditions under which acceptable assessments might be made.

(concluded on facing page)



PERA's new research block, which is nearing completion.

REPORT OF THE MEETING OF COUNCIL

Thursday, 31st January, 1957

THE third Council Meeting of the 1956/57 Session was held at 10 Chesterfield Street, London, W.1, on Thursday, 31st January, 1957. The meeting, at which the Chairman of Council, Mr. H. G. Gregory, presided, was attended by 30 members. Mr. G. C. Oram, Chairman of the Lincoln Section, was present by invitation.

Before proceeding with the business of the meeting, the Chairman read a letter from Miss N. E. Bottom, Honorary Secretary of the Halifax Section, expressing her thanks for the flowers which the Council had sent to her during her illness.

Finance

The Income and Expenditure Account for the period July, 1956/December, 1956, was received by Council, and it was noted that in the main the Institution's finances were running fairly true to budget.

PERA NEWSLETTER — continued

Technical Enquiries

Very heavy demands were made in 1956 on the Technical Enquiry Service, which dealt with nearly 2,000 individual requests for technical assistance from members during the year. Many of these problems necessitated close investigation on the shop floor by the Association's engineers as well as practical investigations in PERA laboratories. These enquiries embrace most aspects of manufacture from the delivery of raw materials to the shipment of finished products, including design for production, machining, deep drawing, die casting, assembly, finishing, inspection, etc. Typical of the economies made by firms applying the Association's recommendations were a saving of approximately £3,000 per annum in the production of bearings ; a reduction of two-thirds in the cost of producing brush boxes by substituting an impact extrusion for a riveted assembly ; a reduction of 160,000 per annum in the number of shells scrapped during deep drawing operations by improving tool design and operating conditions ; and a saving of £2,000 on one order for label frames.

Mobile Unit

During the year the Mobile Unit completed its first tour of members, having visited more than 400 factories and given demonstrations, etc., to about 15,000 industrial personnel. The leading vehicle is equipped as a cinema or lecture theatre, and the trailer can be used as a demonstration bay for talks to workshop personnel. Practical demonstrations of tool grinding and measuring techniques, etc., are also given. A number of films giving practical guidance on impact extrusion, finish blanking, improved grinding techniques, automation, drilling, etc., have been made, and are being shown to factory personnel.

Regional and Section Honorary Secretaries Conference

It was reported by the Finance and General Purposes Committee that in order to encourage attendance at this important Annual Conference, it had been decided that those attending might, if they so wished, make a claim for expenses within limits defined by the Committee.

The next Conference would be held at 10 Chesterfield Street, London, W.1, on Wednesday, 22nd May, 1957.

Nomenclature of Sections

It was reported that the following Sections had agreed to a change of name, in view of the fact that a certain amount of confusion had been arising owing to the inconsistency of the names of some Sections. The changes so far agreed are as follows :

Old Name	*New Name*
Halifax	Halifax and Huddersfield
Yorkshire	Leeds
Eastern Counties	Ipswich and Colchester
West Wales	Swansea
South Wales	Cardiff
North Eastern	Newcastle-upon-Tyne
Southern	Southampton

National Conference, 1957

The Council reaffirmed their decision that a National Conference should be held during 1957, in spite of the difficulties created by oil and petrol rationing.

" Variety Reduction "

The Secretary reported that in conjunction with the British Standards Institution and the British Productivity Council, the Institution had published in booklet form the Papers presented by Professor H. W. Martin, of the Rensslaer Polytechnic Institution, New York, at the Production Conference at Olympia last May, and at the Conference of Standards Engineers, which also took place last May.

Copies of this publication were now available at 5s. each.

Appointment of Education and Technical Officer

The Secretary reported that Mr. F. W. Cooper, B.Sc.(Eng.), M.I.Mech.E., M.I.Prod.E., had accepted the appointment of Education and Technical Officer to the Institution, and would take up his duties on 1st April, 1957.

President, 1957/58

The Chairman of Council announced that Mr. E. W. Hancock, M.B.E., had decided not to offer himself for re-election as President for a second year, although every effort had been made to persuade him to do so.

The Chairman, therefore, gave notice, in accordance with Article 40, that at the next Council Meeting the Finance and General Purposes Committee would recommend that the Rt. Hon. The Earl of Halsbury, President-Elect, would take office as President on 1st July, 1957.

Schofield Travel Scholarships

The attention of Council was drawn to the fact that for a variety of reasons the adjudication of the Scholarship Awards now tended to take place towards the end of the year concerned. The Awards Committee had now decided to advance the closing date for the 1957 Scholarship and to bring back the closing date for the 1958 Scholarship by a short period in each case, so that the two dates would coincide. In this way, two Scholarships would be awarded simultaneously, to cover the two years, and thereafter the timing of the Award would be more appropriate.

Broadening of the Base

It was reported that the discussions between the Finance and General Purposes Committee, the Education Committee and the Membership Committee, on methods of modifying the Institution's examination to give effect to the broadening of the base proposals, had now reached a stage where it was possible to see clearly the direction in which the modifications would go. The Chairman of the Education Committee had given an undertaking to the Finance and General Purposes Committee that complete proposals, supported by a new examination structure and syllabuses for each subject, would be placed before the Council within the next 12 months.

Aircraft Production Conference

It was reported that the Fifth Annual Southampton Section Conference on "Problems of Aircraft Production", held at the University of Southampton on 8th/9th of January last, was again highly successful. The steady increase in the number of applications to attend the Conferences seemed to indicate that these meetings filled a definite need within the industry. The proceedings of the Fifth Conference would be published in the March and April issues of the Journal.

Summer School, 1957

The Education Committee announced that the 1957 Summer School would be held at Ashorne Hill from 24th/28th July, 1957. The suggested theme was "Education and the Professional Production Engineer".

Delft Conference Report

It was reported that the Education Committee were considering the recommendations made in the Delft Conference Report, with a view to submitting their suggestions to Council for further action.

The Journal

It was reported by the Editorial Committee that a new series of leading articles was being planned, which would expand the theme of the article by the President on "The Challenge of the Age", recently published in the Journal. An approach was being made to leading industrialists in other countries, inviting their comments on "How is the Challenge Met Elsewhere ?".

With regard to advertising, a satisfactory level was being maintained, although the effect of the Suez emergency and present national circumstances had to be taken into account.

Promotion of Papers

It was reported that the Editorial and Papers Committees had considered at length ways and means by which members of the Institution, and particularly the younger members, could be encouraged to prepare Papers for presentation to the Institution, in either written or verbal form. It was felt that a useful step would be to appoint in each Section Committee a Papers Secretary, whose responsibility it would be to seek out "local talent" in his own area, and who would also arrange, either through the Section or through Head Office, for intending authors to receive any necessary help in the physical preparation of manuscripts and illustrations.

Institution Papers

The Papers Committee reported that since the last Council meeting, the 1956 Sir Alfred Herbert Paper had been presented to the Institution in Manchester, when Dr. B. V. Bowden, Principal of the College of Science and Technology, had given an outstanding address on "The Development of Technological Education in Europe, America and England". The lecture was followed by a stimulating discussion, and the occasion attracted much notice in the educational and technological world. The Paper and discussion would be published in the February issue of the Journal.

Arrangements were now well advanced for the presentation, in Sheffield, on 18th March next, of the 1956 George Bray Memorial Lecture, when Mr. Stafford Beer, Head of the Department of Operational Research and Cybernetics of The United Steel Companies, Ltd., would speak on "The Scope for Operational Research in Industry".

With regard to the 1957 Sir Alfred Herbert Paper, arrangements had now been made for this to be presented at the Royal Institution, London, W.1, on Thursday, 31st October, 1957, at 6.30 p.m. The speaker would be Dr. H. Barrell, Head of the Metrology Division of the National Physical Laboratory, whose subject would be: "The Bases of Measurement".

Research

The following reports were made on behalf of the sub-committees of the Research Committee :-

Materials Handling. There has been no meeting of the Materials Handling Sub-Committee during the quarter, but at the request of the Finance and General Purposes Committee, the Formation of Divisions Sub-Committee met to investigate the desirability of setting up a Materials Handling Division

within the Institution. As a result of their deliberations, it was decided to recommend to the Finance and General Purposes Committee that the existing Materials Handling Sub-Committee be given the status of a Specialist Group, under the title of "Works Planning and Materials Handling". It was also decided to recommend that the organisation should be on a Regional and Sectional basis and that in the first year the Group Committee be appointed by the Research Committee, but thereafter nominations should be invited from members of the Group. These recommendations are now under consideration.

Material Utilisation. The Sub-Committee has met once during the quarter and the Notes for Guidance of Sections in setting up working groups are now almost complete.

Sources of Information. It is hoped that the final draft of the Directory will be submitted to the Research Committee for approval by 1st March, 1957.

Control of Quality. Considerable progress has been made by the Sub-Committee. It is hoped that the draft report will be ready for submission to the Research Committee for consideration at the March meeting.

Joint Research Committee. The Sub-Committee on "Electronic and Kindred Modern Developments as Applied to Process Loading" has held two meetings. Case studies are being collected and further research is being conducted into these problems.

The Sub-Committee on "The Effective Use of Shiftworking in Industry" is experiencing a little difficulty in getting information from industry, but research into this problem is being continued.

Human Relations in Industry. After considerable investigation by the Research Committee, it has been decided that it would be unnecessary to set up a Sub-Committee on this subject, as nearly all aspects of it have been covered already, but it was recommended that in any report published by the Institution, some space should be devoted to this important matter.

Standardisation

It was reported that the Standards Committee's recommendation for the revision of B.S.1886, having been approved by the Council, had accordingly been submitted to the British Standards Institution, who were taking action in this matter.

Work was progressing in the two Sub-Committees recently set up, on (a) International Standards ; and (b) Unit Heads and Platens.

A meeting of the Joint Advisory Committee with B.S.I. had been held, and it had been agreed that the 1957 Conference of Standards Engineers should be held in London, on Thursday, 9th May, 1957. The Standards Committee are pleased to note that their Chairman, Mr. H. Stafford, has been appointed Chairman of the Conference.

The Committee continues its work of commenting on draft B.S. specifications, and of appointing I.Prod.E. representatives to serve on B.S.I. Technical Committees, by invitation of B.S.I.

Hazleton Memorial Library

It was reported that the Library had had a very busy quarter. Bibliographies have now been compiled on Stress Corrosion of Light Metals ; Automation ; Computer-controlled Machine Tools; Tool Grinding; and Technical Education, in addition to numerous short reading lists on a wide variety of subjects.

The Council were extremely sorry to learn that the Past Chairman of the Library Committee, Lord Sempill, had recently met with an accident, and it was agreed that a message of sympathy and good wishes be sent to him.

Region and Section Reports

The Council received a number of reports from Regions and Sections, extracts from which appear on pages 209 - 213.

Membership

The Council approved a number of recommendations for membership and transfer, details of which are given on pages 207 - 208.

Sections Outside the United Kingdom

Mr. H. W. Bowen, O.B.E. (Vice-Chairman of Council), reporting on liaison with Sections outside the United Kingdom, asked that any member of the Institution who went abroad on business should make every effort to attend meetings of overseas Sections, if there was one in the area visited, or to make contact with the Chairman or Secretary. This was always greatly appreciated by the Sections concerned.

Among visitors to Head Office from overseas had been Mr. S. Krishnamurti, of Bombay, and other visitors were expected in the near future.

The Annual Report of the Secretary to the Australian Council showed that all the Australian Sections had had a very active and progressive year. Further reports of progress had been received from New Zealand and South Africa.

Loughborough College — Appointment of Governor

The Council unanimously adopted the Education Committee's recommendation that Mr. S. Radcliffe, M.I.Prod.E., be nominated to serve on the Board of Governors of Loughborough College for a further period.

Honours

The Council were pleased to record that Her Majesty the Queen had conferred the following awards on members of the Institution :-

O.B.E. — Mr. C. D. Alder, Member.
M.B.E. — Mr. W. D. Hopkins, Associate Member.

Obituary

The Chairman referred to the sad loss which the Council had sustained by the death of Mr. Tom Fraser, C.B.E., Hon.M.I.Prod.E., Member of Council. Mr. Fraser had given long and valuable service to the Institution. During his period of membership he was President of the Manchester Section, Chairman of Council, and a Trustee of the Institution. (An appreciation of Mr. Fraser appears on page 214 of this Journal.)

The Chairman also referred to the death of Mr. J. D. Frier, Member, who had served on the Joint Examination Board for many years. In addition, the Council recorded with deep regret the deaths of the following :-

Members : H. J. Bavington ; G. S. Blackburn ; L. Carter ; D. M. Doak ; E. R. Schofield ; J. E. Steel ; L. H. Wadsworth.

Associate Members : H. G. Jenkins ; H. Low.

Associate : A. F. Hamilton-Jenkins.

Student : A. G. Orchard.

Date and Place of Next Meeting

It was agreed that the next meeting of Council should be held at 10 Chesterfield Street, London, W.1, on Thursday, 25th April, 1957.

REPORT OF THE ANNUAL GENERAL MEETING

Thursday, 31st January, 1957.

THE 35th Annual General Meeting of the Institution was held on Thursday, 31st January, 1957, at 2 p.m., at the headquarters of the Institution, 10 Chesterfield Street, London, W.1. The President, Mr. E. W. Hancock, M.B.E., was in the Chair.

Notice Convening Meeting

The Secretary (Mr. W. F. S. Woodford) read the notice convening the meeting.

Minutes

The Minutes of the previous Annual General Meeting, held on 26th January, 1956, which had been published in the January, 1957, Journal, were taken as read and confirmed on the motion of Mr. J. H. Winskill, seconded by Mr. E. Percy Edwards, and were signed as correct.

Election of Members to Council

The Report on the Election of Members to Council, also published in the January, 1957, Journal, was received on the motion of Mr. A. Betts Brown, seconded by Mr. R. Hutcheson.

Annual Report of Council

Mr. H. G. Gregory (Chairman of Council) moved that the Annual Report, which was published in the January, 1957, issue of the Journal, be taken as read and adopted. Mr. F. T. Nurrish, M.B.E., seconded the motion.

The President invited questions or comment and, none being forthcoming, put the motion for the adoption of the Report, which was carried unanimously.

Statement of Income and Expenditure, Balance Sheet and Auditors' Report

On the motion of the Chairman of Council, seconded by Mr. H. Burke, the accounts were adopted.

Election of Auditors, 1956/57

On the motion of Mr. J. H. Winskill, seconded by Mr. A. S. Johnstone, Messrs. Gibson, Appleby & Company, Chartered Accountants, were re-elected Auditors to the Institution for the year 1956/57, and thanked for their previous services.

Election of Solicitors, 1956/57

On the motion of Mr. J. M. Brice, seconded by Mr. G. R. Blakeley, Messrs. Syrett & Sons were re-elected Solicitors to the Institution for the year 1956/57, and thanked for their previous services.

Votes of Thanks

The President said it was the privilege of the reigning President to propose a vote of thanks to the immediate Past President, Past Chairman of Council, and Past Vice-Chairman of Council, and to all the officers of the Institution. He always liked to thank

publicly those who had given their services freely in the endeavour to forward an activity of real worth, and the present was a typical occasion for doing so.

He wished to pay tribute to his predecessor as President, Sir Leonard Lord, whom he had known ever since they had been young production engineers together. Although members might not have seen a great deal of Sir Leonard in person, he had done, and no doubt would continue to do, a considerable amount of work in the interests of the Institution. There were many ways in which Presidents could help the Institution, and Sir Leonard's way had helped it considerably.

Next, there was the man who had really run the Institution, the Past Chairman of Council, Mr. G. Ronald Pryor, who typified the attributes to which the President had just referred. Mr. Pryor was a completely unselfish man ; wherever in the country he was required, he was there. He had a kindly approach and an ability to make one feel that he agreed with one, although in fact he was violently opposed, which was a valuable attribute of any Chairman who wished to create a democratic atmosphere. The President knew that he expressed the feeling of every member of the Institution in thanking Mr. Pryor for his excellent service and for the charming way in which he had given it.

Another man to whom the Institution was most grateful, who had been Vice-Chairman of Council and was now Chairman, was Mr. H. G. Gregory, who had the ability to create a free and democratic atmosphere in which to discuss any problems which arose. If there were not differences of opinion in the Council, its members might as well do what was done in some other Councils, and vote by proxy ; but in fact there was full freedom of speech, thanks to the wonderful pattern set by Mr. Pryor and Mr. Gregory.

The President also paid tribute to the permanent officers of the Institution, and particularly to the Secretary, Mr. Woodford, and the Deputy Secretary, Mr. Caselton. He would like to name all the members of the staff, but he knew that they would excuse him if he did not go through the list. It was difficult to satisfy production engineers, but they were all very pleased with the way in which Mr. Woodford got to the point and satisfied the majority, and with the way in which he ran the organisation at headquarters.

Mr. E. N. Farrar, who seconded, reinforced what the President had said about Mr. Pryor's helpful assistance to the ordinary members of the Council, and also what he had said about the permanent staff.

The vote of thanks was carried by acclamation.

Mr. F. Woodifield proposed a vote of thanks to the President for his conduct of the meeting, and also for all the work which he had done for the last six months as President, and over the very many years during which he had worked for the Institution.

The vote of thanks was carried by acclamation.

The President, responding, thanked Mr. Woodifield for his kind words, and the meeting for the reception given to them. Although it was not on the agenda, he felt that they should place on record the gratitude which they all felt for the wonderful work which was being done by the Chairmen, Secretaries and Committees of all the Sections and Regions. In going about the country in the last few months, nothing had heartened him more, or given him a greater feeling of security, than to see this good work which was being done and to talk to these men, who were doing a splendid job of work during the day and giving their spare time to help the Institution.

He also thanked very sincerely the Chairmen, Secretaries and members of the Standing Committees, who were laying a foundation which was going to give the Institution absolute security.

The meeting then terminated.

ELECTIONS AND TRANSFERS

31st January, 1957.

ADELAIDE SECTION

Transfer
From Graduate to Associate Member
M. Williams.
New Affiliated Firms
G.P.O., Postmaster Generals Department ; Lightburn & Co. Ltd.

BIRMINGHAM SECTION

As Member
I. H. Macqueen.
As Associate Member
R. O. Watts.
As Graduates
M. B. Blunn; S. A. Hobbs; D. H. Butler; J. I. Goddard-Watts; H. M. Roberts; D. Dawson; A. S. Robinson.
As Students
R. O. Parry; D. A. Taylor; C. R. Mortimore.
Transfers
From Graduates to Associate Members
R. E. Sawyer; J. A. Helps; C. A. Rawes; J. E. Richards; J. E. Bill; P. G. Collishaw.
From Students to Graduates
G. B. Lee; M. Smith.

BOMBAY SECTION

As Graduate
D. M. Bhat.
As Student
R. A. Katiyar.
Transfer
From Associate Member to Member
L. Mac P. Brookes.

CALCUTTA SECTION

As Student
T. N. Rao.

CORNWALL SECTION

New Affiliated Firm
J. & F. Poole Ltd.
Transfer
From Graduate to Associate Member
W. O. Vivian.

COVENTRY SECTION

As Associate Member
E. A. Tilt.
As Graduates
R. F. Howes; P. A. Mason; G. Horton; D. R. J. Price.

As Students
B. T. Walker; E. Mawdsley; C. H. Garner; J. H. Salt.
Transfers
From Graduates to Associate Members
J. D. Haigh; J. S. Sanders; C. J. Emery; J. E. Sedgwick.
From Students to Graduates
J. M. Nunn; R. C. Simmonds.

DERBY SECTION
Transfers
From Graduates to Associate Members
F. W. Beeken; P. N. Johnson.
From Students to Graduates
K. Janes; J. S. Lowther.

DUNDEE SECTION
As Associate Member
A. McKay.
As Graduate
B. A. Farquharson.
As Student
Y. P. Singh.
Transfer
From Student to Graduate
D. C. Paterson.

EDINBURGH SECTION
As Graduates
A. J. C. Johnston; W. S. Dobson.
Transfer
From Student to Graduate
D. A. Bowman.

GLASGOW SECTION
As Associate Members
A. W. J. Chisholm; G. Barr; M. C. Rodger.
As Students
G. A. Leeper; W. Ferguson.
Transfers
From Associate to Associate Member
E. S. Dunthorne.
From Graduates to Associate Members
L. R. Richardson; M. Coll; J. A. E. Shand.

LEICESTER SECTION
As Students
E. H. Hanley; T. N. Bennett.
Transfers
From Graduates to Associate Members
H. Maden; E. D. Lodge; S. J. Cook.
From Student to Graduate
J. Cooper.

LINCOLN SECTION
As Student
P. L. Primrose.
Transfers
From Graduate to Associate Member
J. K. Willcock.
From Student to Graduate
B. O. Hinitt.

LIVERPOOL SECTION
Transfer
From Graduate to Associate Member
D. Whitehead.

LONDON SECTION
As Members
J. Harrison; E. J. Peplow; W. L. Biscoe; A. P. Fowler.
As Associate Members
W. H. Howes; D. C. Gohm; A. J. Jones; I. S. Morton; G. W. Thornley; L. A. Prescod; D. C. Pollard; G. E. Evans; A. Brodie; R. G. Roden.
As Graduates
D. L. Goring; F. R. Williams; C. H. T. Wang; J. G. Payton; T. R. Machin C. G. Irving; K. J. Buckton; T. R. H. Tilley; P. Dyce; D. W. Orchard; J. Murdoch; W. Longthorne; S. F. Cogger; D. R. Heath; S. R. Foulser; M. Thornton; B. J. Pepper.
As Students
R. C. Scott; C. W. Barfoot; D. D. De-Vote; P. J. Solly; B. J. Starck; P. R. B. Charles; S. F. M. Samy; B. C. Collins; P. G. Jupp.
Transfers
From Graduates to Associate Members
P. J. Hawkins; K. E. Johnson; J. J. Peck; G. H. Briscoe; C. B. Hubbard; S. S. Barton; H. G. Shakeshaft; A. E. Clauson; J. Brooksbank; D. A. L. West; A. D. McLean Hill; S. Jovanovitch; G. A. Felton; D. L. Morgan; D. A. Craven; A. C. Jordan; H. A. Blomiley; W. D. Wilson.
From Students to Graduates
J. K. Carpenter; R. H. Banks; A. R. Stevens; E. H. Dennis; L. T. D. Taylor; D. H. Pattenden.
New Affiliated Firm
The British Tabulating Machine Co. Ltd.

LUTON SECTION
As Graduates
J. D. Bryant; D. R. Sherwood.
As Students
K. L. Reynolds.
Transfers
From Graduates to Associate Members
J. F. Turgoose; R. Gunnell; J. L. Caine.
From Student to Graduate
D. E. Mack.

MANCHESTER SECTION
As Associate Member
A. R. Rothwell.
As Graduates
H. Scott; H. Moran.
As Student
G. A. Mills.
Transfers
From Graduates to Associate Members
J. D. Pennington; G. G. Stewart; A. J. Lamb.
From Student to Graduate
A. A. Davenport.

MELBOURNE SECTION
As Associate Member
R. A. Young.
As Student
A. K. Kenworthy.
New Affiliated Firm
Postmaster Generals Department.

NEW ZEALAND SECTION
Transfer
From Graduates to Associate Members
L. L. Chadderton; E. Sullivan.

NORTH EASTERN SECTION
As Graduates
T. Miller; W. M. Thompson.
As Student
G. Reynolds.
Transfers
From Associate Member to Member
C. E. Darlington.
From Graduate to Associate Member
F. Hancock.

NORTHERN IRELAND SECTION
As Associate Member
H. Magowan.
As Students
J. C. McCrone; J. D. Magill.

NOTTINGHAM SECTION
As Graduate
J. R. Kelly.

OXFORD SECTION
As Graduates
R. F. Ferguson; R. F. Langston.

PETERBOROUGH SECTION
As Member
M. I. Prichard.
As Graduate
P. J. Habershon.
Transfer
From Associate Member to Member
W. Peck.

PRESTON SECTION
As Associate Member
J. Harrison.
As Students
E. Wearden; R. Higginbottom; J. K. Sager.
Transfers
From Graduates to Associate Members
T. Woodall; J. E. Horncastle.

READING SECTION
Transfer
From Graduate to Associate Member
R. H. Poole.

ROCHESTER SECTION
As Students
D. B. Hurst; G. B. Simmons.

SHEFFIELD SECTION
As Member
J. D. Joy.
As Associate Member
C. Sargent.
As Graduate
N. Vollans.
As Student
M. C. Hewitt.
Transfers
From Graduate to Associate Member
R. Hallam.
From Student to Graduate
R. Horsley.

SHREWSBURY SECTION
As Associate Member
G. A. Crook.
As Student
K. H. Trumper.
Transfers
From Graduate to Associate Member
F. R. Collinson.
From Student to Graduate
A. Brice.

SOUTH AFRICA SECTION
As Member
T. F. B. de Villiers.
As Student
M. J. Parker.
Transfer
From Graduate to Associate Member
P. G. McGlynn.

SOUTHERN SECTION
As Graduate
P. C. Waite.
As Students
D. Cookson; S. D. Allanson.

SOUTH ESSEX SECTION
As Graduates
J. K. Yates; S. B. Hancock.
Transfers
From Graduate to Associate Member
J. D. Thomson.
From Student to Graduate
G. J. Richards.

STOKE-ON-TRENT SECTION
Transfers
From Graduates to Associate Members
R. M. Hunt; E. A. Triggs.

SYDNEY SECTION
As Graduates
J. A. Ackerman; R. A. Young.
As Students
J. D. Glover; I. A. Hamilton.
Transfer
From Graduate to Associate Member
J. R. C. Leach.

TEES-SIDE SECTION
As Graduate
F. Bond.
Transfer
From Graduate to Associate Member
K. MacDonald.

WESTERN SECTION
As Associate Members
D. Liptrot; R. W. Grow.
As Students
R. A. Pitman; M. C. Staley; G. D. Slegg.
Transfer
From Student to Graduate
M. R. Pengelly.

WOLVERHAMPTON SECTION
As Graduate
A. B. Caine.
As Students
F. A. Lowe; G. Smith.
Transfers
From Associate Members to Members
C. A. Stevens; M. J. Cowell.
From Graduates to Associate Members
E. Springthorpe; T. D. H. Thorpe; J. H. Bailey; E. J. Bradley; G. Lee; J. E. Walford.
From Students to Graduates
T. H. Jenkinson; B. J. Ghoshal.

WORCESTER SECTION
Transfer
From Graduate to Associate Member
K. J. Orton.

YORKSHIRE SECTION
As Graduate
W. Beveridge.
Transfers
From Students to Graduates
P. Stewart; M. H. Parkinson.

NO SECTION
As Associate Member
F. H. J. Edwards.
As Graduate
S. S. Sodhi.
Transfers
From Graduate to Associate Member
J. Spiegel.
From Student to Graduate
B. J. Braganza.

EXTRACTS FROM REGION AND SECTION QUARTERLY REPORTS

EASTERN REGION

Regional Report

The first Regional meeting of this session was held at Ipswich in November, when Sir Walter Puckey gave an address on "Automation — Does It Concern You ?". The excellent arrangements were carried out by the Eastern Counties Section, under the Chairmanship of Mr. F. T. Dyer. About 200 members and visitors attended, including a party of senior students from Ipswich School.

Sir Walter's inspiring address was well received and in a lively discussion many aspects of automation were considered.

In proposing the vote of thanks, the Regional Chairman, Mr. E. N. Farrar, referred to Sir Walter's many services to national and Institution activities.

Eastern Counties

During October a joint meeting with the Colchester Engineering Society was held in Colchester, when Mr. A. Talbot, M.I.B.F., gave a Paper on "Jobbing Foundry Work Today". This meeting was well attended and the Paper was illustrated by films and slides.

In December, a Paper on "The Use of Punched Card Methods for Production Control" was given by Mr. J. C. Davies, A.C.I.S., A.A.C.C.A. This was a well attended and very informative lecture followed by an interesting discussion.

A very interesting highlight of this quarter was the Committee meeting held in Ipswich during October when Mr. W. F. S. Woodford was present, thus enabling many points to be discussed with a Head Office representative in attendance.

The Section Committee are making great efforts to strengthen the representation on the Committee, and the Chairman recently welcomed Mr. H. Hudston who has willingly offered his services.

Other routine matters discussed at the monthly Committee meetings have included membership applications, and the possibility of holding Section visits again next summer, together with a possible Social Function.

EAST & WEST RIDINGS REGION

Halifax

At a recent meeting of the Halifax Senior Section Committee, the Chairman reported that the Halifax Technical College had enlarged its syllabus to enable students who were qualifying for the Higher National Certificate in Mechanical Engineering, to qualify also for membership of the Institution.

The Chairman felt that this step forward was due, to a great extent, to the work that had been done by the Section Committee in pressing for this facility at the local technical colleges.

A well attended lecture, given by Mr. W. A. Hannaby, Chairman of the Halifax Section, was held at The White Swan Hotel, Halifax, in December. Mr. Hannaby chose the subject "The Application of Drilling Machines".

Discussion after the lecture was stimulated by the excellence with which the subject matter was delivered.

Sheffield

Following a discussion between a Committee Member and a college official, the Department of Commerce and Management has arranged to present two series of courses on Electrical Digital Computers, to begin early in 1957. The first series of three lectures is designed for those wishing to assess the potential value and application of the technique, and the second series of six lectures will be primarily concerned with detailed applications and potentialities.

Yorkshire

The 1956/57 Session is now in full swing and one Regional and two Section meetings have already been held.

With reference to the Chairman of Council's letter regarding Papers for publication, the Committee discussed this matter and are doing everything possible in this respect.

MIDLANDS REGION

Birmingham

In October, the lecture on "Safety as Seen by the Production Engineer", by Mr. J. Silver, M.I.Prod.E., was read in the author's absence by Mr. J. Sutton. This was followed by "Safety as Seen by the Factory Inspector" by Mr. A. Hillier. The meeting was well attended and promoted a lively discussion.

The November meeting, when a lecture on "The Use of Isotopes in Industry" was given by Dr. H. Seligman, Ph.D., was one of the finest lectures ever given to this Section and it was illustrated by a film showing some of the work done at the Atomic Energy Establishment, Harwell. Dr. Seligman also gave demonstrations concerning radio-activity.

The Section has formed an *ad hoc* Committee to review publicity, public relations and Section policy. Their report will be issued early in the New Year.

In December, the President of the Institution, Mr. E. W. Hancock, M.B.E., Hon.M.I.Prod.E., gave a Paper on "People in Industry: The Changing Pattern of Industrial Society".

The Section held a very successful Buffet Dance on December 8th, when over 250 members and their friends attended a most enjoyable function.

The Chairman announced the plans for the One-Day Conference "Tooling Tomorrow's Production", and confirmed that several eminent speakers had accepted the invitation to address the Conference. The date and programme will be announced shortly.

Coventry

Attendances at lectures this Session have been most gratifying and so far well above average for 1955/56. Approximately 170 members and visitors attended the lecture in November on the subject "Modern Contour Turning", which was illustrated by colour films produced by the G. F. Fisher Company, of Switzerland. A most interesting discussion followed and many questions were admirably and capably dealt with by a member of G. F. Fisher Company's staff.

The Annual Dinner-Dance held in October was once again a most successful and enjoyable event ; among the guests were the Mayor of Coventry, the President of the Institution, Mr. E. W. Hancock, M.B.E., and a number of local industrialists.

The Committee accepted with regret the resignation of Mr. W. T. H. Golding, a Rugby member who has moved to Northern Ireland. In his place, Mr. Cribb was unanimously co-opted to the Committee.

Wolverhampton

The October lecture, "Electronic Control in Industry" by Mr. E. Heys, A.M.I.E.E., was well attended. The practical applications were well chosen and served admirably to substantiate the foregoing explanation of the theory involved.

Following the customary practice of holding one meeting each Session in Stafford, a lecture on "Management and Organisation" was given by Mr. E. L. G. Robins, B.Sc.(Eng.), at the County Technical College.

The Regional Meeting has been the outstanding event in Wolverhampton, when the President of the Institution, Mr. E. W. Hancock, M.B.E., gave the Midland Regional address. Due to the difficulties of transport arising out of the petrol situation, the attendance was below normal, but the 120 people attending were enthusiastic in their appreciation of the President's first-rate Paper entitled "People in Industry — The Changing Pattern of Industrial Society".

Wolverhampton Graduate

In October, a very interesting Paper was given by Mr. E. Heys, A.M.I.E.E., on "Electronic Control in Industry", which proved to be a most interesting subject and aroused a lively discussion. It was agreed to have a continuation of this Paper early in the next Session. Also, in October, a

visit was made to the Works of Messrs. Deritend Stamping Co. Ltd., Birmingham. The party was conducted round the general and technical offices where various forgings were seen in the planning stage on drawing boards, etc. The machine shops, tool rooms, die shops and stamp shops were also visited.

In November, a lecture was given by Mr. G. S. Rowland on "Designing for Production". It was an interesting Paper which led to a good discussion on many design problems. Also, in November, a visit was made to the Company of Messrs. Webley-Scott Ltd., Birmingham.

In December, a visit was made to the rolling mills of Ductle Steels Ltd., Willenhall. The Midlands Region held a Regional Meeting in December, when the address was given by the Institution's President, Mr. E. W. Hancock, M.B.E., on "People in Industry — The Changing Pattern of Industrial Society". Also, in December, the Wolverhampton Section held their Annual Dinner-Dance which proved to be a great success.

The Graduate Committee continue to hold monthly meetings and attendances are good. A number of younger men have been co-opted to the Committee and they should prove to be an asset in the future.

The members of the Wolverhampton Graduate Section take a keen interest in their Section Programme and attendances and quality of lectures have been much higher than in previous years. Visits form a valuable part of the Graduates continued study.

NORTHERN REGION

North Eastern

At the October meeting, a Paper was presented by Mr. A. Harvey, the subject being "Materials Handling for Batch Production". The Paper had been prepared by Mr. Rattlidge, who is a member of the Materials Handling Sub-Committee, and was read by Mr. Harvey.

During November, Mr. C. Cashmore, A.I.M., assisted by Mr. D. Edwards, presented a very interesting Paper under the title "The Manufacture and Some Applications of Seamless Metallic Tubes". Some very interesting products, illustrating the application of the various tubes were exhibited.

The December meeting was in the form of a film evening and the members' ladies were invited. At the opening of the meeting, Mr. C. Noble, who was Chairman of the Section during the years 1944/46, presented the Section with a Chairman's Jewel of Office. The presentation was made to the Chairman, Mr. H. B. Topham, who thanked Mr. Noble for his kindness and expressed appreciation of Mr. Noble's continued service to the North Eastern Section.

Tees-Side

The lecture meeting programme for the 1956/57 Session is now well under way. Rearrangements of lectures and dates at short notice for the first two meetings adversely affected attendance.

A most successful meeting was held at Darlington in November when Mr. Henderson, of Messrs. C. A. Parsons, gave his talk on "The Selection of Machine Tools for Heavy Engineering Production". This lecture attracted visitors from almost every heavy engineering company in the area.

Members and vistors attending the meetings usually have to travel some distance. With the advent of petrol rationing it is felt that it may have an adverse affect on attendance.

NORTHERN IRELAND REGION

Northern Ireland

During the period under review, three successful lecture meetings have been held. The first, held in October, was entitled "Production Control — 'Hollerith' Punched Card Applications" and given by Mr. J. McBurnie, Northern Ireland Sales Manager, The British Tabulating Machine Co. The lecture proved to be of great interest and was illustrated by a film.

The November lecture was given by Mr. G. W. Williamson, O.B.E., M.C., a well-known figure in local engineering circles. His subject was "Incentive Schemes for Maintenance", and some lively discussion was generated by the interesting material presented.

Mr. O. S. Puckle, M.B.E., M.I.E.E., from E.M.I., gave a lecture on "The Electronic Control of Machine Tools" in December, the subject being directly related to the more comprehensive term "Automation", and with the excellent manner of presentation, considerable interest and discussion was evoked.

NORTH MIDLANDS REGION

Leicester

The lecture on "The Education of the Production Engineer in Industrial Engineering" by Mr. J. France, M.I.Prod.E., provoked lively and interesting discussion.

The Section Annual Dinner was held in November when the chief guests were Mr. E. W. Hancock, M.B.E., President of the Institution; Mr. C. N. Wilson, Principal of University College, Leicester; and Alderman A. Halkyard, C.B., M.C., T.D., D.L., LL.B., Lord Mayor of Leicester. Other guests included many prominent local company executives, and the Section were particularly pleased that Dr. Haslegrave, Principal of Loughborough College of Technology, was present. The attendance at the Dinner was an all-time record, which indicates that the Annual Dinner is fast becoming a local event of some importance.

The Peterborough Section was represented by Mr. W. E. Peck and Mr. Harris. The Leicester Section feel that more contact between local Sections would enhance and strengthen the status of the Institution as a whole.

At the November Committee meeting, the inauguration of a Leicester Committee Prize, to the value of £5 for a best Paper on any "Production Engineering" subject, was announced. Authorship is limited to students and graduates of the Section, and the closing date for receipt of entries is 31st March each year.

Lincoln

Since the last quarterly report three lecture meetings have been held. In September, Mr. Webber, of I.C.I. Ltd., read a Paper on "Work Study as Applied to Engineering Operations" at Scunthorpe. The attendance at this meeting was very good.

A meeting was held in Grantham in October when Mr. P. Spear, B.Eng., Grad.I.Prod.E., read a Paper on "Industrial Research". This was a joint meeting with Grantham Enginering Society.

The third meeting was held in Lincoln in December when Mr. Cowlishaw read a Paper on "Automation".

The Lincoln Section are very grateful for the support and help received from Head Office towards the success of the Fourth Annual Dinner-Dance.

Nottingham

The first half of the winter Session is now over and three successful lecture meetings have been held, the subjects being "The Ings of Industry"; "The Design and Manufacture of Springs"; and "The Fundamentals of Progressive Tooling".

This Session, an innovation has been tried out whereby the formal invitation ticket for lecture meetings has been replaced by a circular letter from the Section Honorary Secretary. It is evident that this more personal approach has resulted in an increased attendance at meetings.

A further effort to increase membership will be made early in January, when engineering apprentices from local industry will be invited to attend a specially arranged meeting to discuss, informally, several aspects of production engineering, which wind up the aims of the Institution. A panel of prominent members from the Nottingham Section will introduce the various subjects for discussion.

Peterborough

During the past quarter three lectures have been given of widely differing aspects with good attendance.

The first, held in October, was by Mr. F. E. Butcher, who lectured on "Design for Production".

In November, a joint meeting with the Peterborough Section of the Incorporated Plant Engineers was held. The speaker was Mr. A. Rivers-Fletcher, who gave a running commentary on a series of films under the title "The Development of the B.R.M. Racing Car".

"Nuclear Power and its Effect on the Production Engineer" was the title of a lecture given in December by

Mr. I. Munro, B.Sc. Mr. Munro traced the history and development of nuclear power and spoke of the need for an alternative source of power other than coal and oil. He went on to give statistics concerning the efficiency of Calder Hall Power Station.

NORTH WESTERN REGION

Regional Report

The lecture programmes within the Region are now under way, and most Sections have had two meetings.

Arrangements are now complete for the Third North Western Regional Dinner which takes place at the Midland Hotel, Manchester, on Friday, 8th February, 1957, and the following have accepted invitations to attend: the Lord Mayor of Manchester; Mr. H. G. Gregory, Chairman of Council; Mr. F. J. Erroll, Member of Parliament; Dr. B. V. Bowden, Principal, Manchester College of Science and Technology; and Mr. W. F. S. Woodford, Secretary of the Institution.

Officers of the North Western Regional Sections were invited to attend the reception at the Midland Hotel, Manchester, prior to the very successful "1956 Sir Alfred Herbert Paper", which was held at the Manchester College of Science and Technology.

Manchester

The October lecture, entitled "Computer Controlled Machine Tools", was given by Mr. D. T. N. Williamson, of Ferranti Ltd. Attendance was good and the discussion was of a high standard.

The November lecture was given by Mr. H. Hayes and was entitled "Modern Forging Practice".

The Manchester Section Committee are pleased to announce that Mr. H. Spencer-Smith, M.I.Prod.E., has been co-opted to the Membership Committee.

The Section Chairman, Mr. T. A. Stoddart, attended the Centenary Celebrations of the Manchester Association of Engineers.

The Committee members and their wives held their Second Annual Social Evening at the Chelford in October, which proved to be highly successful.

The 1956 Sir Alfred Herbert Paper was held this year in Manchester, and Dr. B. V. Bowden, M.A., M.I.E.E., the Principal of Manchester College of Science and Technology, gave an excellent Paper which stimulated a most interesting discussion.

Manchester Graduate

Two lecture meetings and two works visits have been held so far this Session and both lectures had about the average attendance of 30. A proportion of 10 members to 20 visitors is the usual attendance. On the works visits the attendance was 20 in each case, the majority being members.

Preston

The first of the winter lectures, held in conjunction with the Preston Productivity Committee, was given by Mr. F. G. Woollard, M.B.E., Hon.A.C.T.(Birm.), M.I.Mech.E., M.I.Prod.E., M.I.I.A., M.S.A.E., at Preston. The meeting was attended by 80 people and Mr. Woollard spoke on the various aspects of "What Automation Means", the lecture being well illustrated by slides. The subsequent discussion was capably dealt with by the lecturer to the benefit of all concerned.

The second lecture, also held at Preston, in November, was given by Mr. T. W. Elkington, M.I.Prod.E., on "Special Purpose Unit Head Machines". Those attending were amply rewarded, especially by the lecturer's capable handling of the discussion which centred around the practical problems associated with the topic under review.

The Chairman of the Section, Mr. F. Grimshaw, O.B.E., M.I.Prod.E., has now returned from his visit to India, and thanks are due to Mr. W. L. Jones, M.I.Prod.E., Vice-Chairman, who has dealt with Section affairs during Mr. Grimshaw's absence.

Stoke-on-Trent

In July last, Mr. H. A. Armstrong succeeded Mr. H. Porter as Chairman of the Section. Mr. Porter was Chairman of the original Sub-Section and first Chairman when the Sub-Section was raised to Section status. The Committee passed a warm vote of thanks to Mr. Porter on relinquishing office.

During the absence of Mr. W. R. Bailey, who is attending a PERA course for his firm, Mr. A. Macdonald, the Section Vice-Chairman, has been Acting Honorary Secretary.

In October, Group Captain F. C. V. Laws, C.B., C.B.E., gave a most interesting lecture on "Aerial Photography in Peace and War" and drew a record attendance of 85. Many were from local photographic societies.

In November, Mr. M. O. Short, of Metropolitan-Vickers, gave a lecture on "Cutting Tools — Application and Research". This was a most interesting and enjoyable evening and Mr. Short's address brought forth a lively discussion.

This Session the venue of the Section meetings has been changed in order to provide better amenities for members. The Committee hope that by their decision the members will have more incentive to attend the lecture meetings.

SOUTHERN REGION

Oxford

The first lecture meeting of the 1956/57 Session was held in September in Oxford Town Hall. Over 159 people were present to hear Messrs. J. J. Stordy and W. G. J. Appleton lecture on "Industrial Finishing Technique and Practice".

The Session's second lecture was in the north of the Section's area at Banbury. Mr. J. A. Ambler, a development metallurgist of the Northern Aluminium Company, gave a most interesting lecture on the subject "Aluminium as a Packaging Material".

The November lecture was held in Aylesbury, the first time the Section has visited this town. There was a most gratifying response to Mr. P. G. Pentz's lecture "Making Jigs, Tools and Gauges in Epoxide Plastics" and it is intended to hold further lectures in this area.

Reading

The Reading Section will be holding their Annual Dinner on the 1st March, 1957. The Section has been honoured by the President, Mr. E. W. Hancock, M.B.E., who agreed to attend as Guest of Honour. The Dinner will be held at the Mill House Country Club, and musical entertainment will be arranged.

Southern

This winter, lectures have been held at Weymouth and Christchurch and, without comment on text or speakers, there was a considerable audience in both instances, with the help of local industry and the Royal Aeronautical Society.

SCOTTISH REGION

Dundee

Three very interesting and instructive lecture meetings have been held during this quarter.

The October lecture on "Machine Tools from Wilkinson to Automation" was given by Mr. R. Gabriel, who dealt briefly with the highlights of machine tool history up to the present day.

The November lecture was the case history of the first Voith Schneider propellers to be made in this country, and was given by Mr. A. Betts Brown, of Edinburgh. This is the type of propeller that is used by the local Tay Ferries. Mr. Brown first dealt with the fundamental principles behind the design of this mechanism and then with the difficulties of casting, fabrication and adjustment. A film illustrating this propeller's unique manoeuvring characteristics was also shown.

In the December lecture by Mr. D. Irvine, of Dundee, some aspects of motion study for light industry were illustrated by diagrams and films. Some of the lecturer's illustrations showed production increased up to 600% and weight handled reduced from eight tons per day down to a few pounds.

The Committee are extremely grateful to the lecturers for the effort in preparing their Papers, and also for their expert answers to the many questions put to them at discussion time.

SOUTH EASTERN REGION

Regional Report

On 4th December. 1956, the Annual Dinner-Dance of the Region, held at the Savoy Hotel, London, was a most

successful function, at which the Region had the pleasure of welcoming as the chief guests, the President of the Institution, Mr. E. W. Hancock, M.B.E., and Mrs. Hancock.

It has been decided that an award should be instituted to promote the interest of the Region graduate members in the preparation of Papers. A draft of the rules controlling the award has been considered by the Regional Committee and is to be studied by the Section Committees. As soon as the details of the scheme have been finalised, they will be presented to the members of the Region.

For some six years past, the London Section has held lecture meetings in Brighton in view of the industrial development going on around the town in an area that includes places like Crawley. Further, the increase in the status of the Brighton Technical College will give more importance to the area from the point of view of the Institution. It has been decided to increase the facilities for holding meetings in the Brighton and Crawley districts and with this in view a local committee is being set up to organise meetings in the area, instead of the whole of the work being done by the main London Section Committee, as in the past.

The Regional Committee have made a recommendation that for the 1957/58 Session the various Sections in the Region should endeavour to plan their lecture programme with the common theme " The Speed of Technical Advance in Great Britain " and that the Regional meeting in April, 1958, should be based on the same theme.

The South Eastern Regional Committee have for some time been considering ways by which the Regional scheme could be operated to the benefit of the members of the Institution. It is felt that the Regional organisation can so easily develop into a superfluous layer between the Sections and Council, unless Regional Committees are very alive in promoting activities and doing useful work that cannot be done so well at Section level.

London

July/September, 1956

A full lecture programme covering a wide variety of topics has been prepared for the coming Session and work has been started on the preparation of the programme for the 1957/58 Session.

The Brighton Sub-Committee arranged a most interesting and enjoyable visit for members and their friends residing in the Sussex area, to the Ocean Terminal Building at Southampton Docks in July.

The usual social events have been arranged ; the Regional Dinner and Dance on the 4th December and the Section Annual Stag Dinner on the 13th February.

September/October, 1956

Successful and well attended lecture meetings have been held on " The Impact of the Production Engineer on the Work and Payment Structure of Industry " by Dr. Elliott Jacques, an eminent sociologist ; and " Automation of Batch Production, the Role of Work Study " by Mr. Ian Nickols, Managing Director of Oxted Mills Ltd.

A meeting was held at Brighton on " Materials Utilisation " by Mr. H. L. Madeley. The lecture was followed by a general meeting to discuss the future progress of the Brighton Group ; a further lecture meeting was held at Croydon on the subject of " Electronics as an Aid to Production — with Special Reference to the Aircraft Industry ". This lecture was given by Mr. T. A. Waite, and was most interesting.

London Graduate

The London Graduate Section would like to open this report for the January Council meeting by placing on record their sincere thanks and deep appreciation of the services of two Committee members who have recently retired, namely, Mr. W. M. Bull, Committee member from 1954 - 1956 and Mr. F. H. Johns, Committee member 1951 - 1956 and Section Chairman 1954 - 1956.

The London Graduate Section has two Committee members at present serving on the H.M. Library Book Selection Sub-Committee, namely, Messrs. J. D. Parson and R. J. Temple, and three further members of the London Graduate Section are to be co-opted to the Sub-Committee to bring it nearer to its optimum strength. They are Messrs. W. E. Bland ; D. R. Lawson ; and W. E. G. Speakman.

During the period under review, the Seventh Weekend School has been held at the Beatrice Webb House, near Dorking. It was attended by 27 non-Corporate members and visitors. The School commenced with a lecture entitled " Management and its Application to Maintenance " given by Mr. R. W. Maling, who illustrated the reasons for maintenance in order to obtain efficient output and reduce time wastage, continuing with the method employed by I.C.I. to ensure this efficiency.

Session II consisted of a joint lecture entitled "Comparisons of Hydraulics and Pneumatics in Industrial Applications " by Mr. L. A. Darby and Mr. B. B. Bowles.

The lecture in Session III was given by Mr. C. E. G. Bailey, on " Computers in Industry ".

The fourth and final Session was devoted to a lecture entitled " Packaging — The Final Stage of Production " prepared by Mr. A. A. Howgrave, O.B.E., and read by Mr. W. Sivier in his absence.

The London Graduate Section Committee would like to express their thanks to Mr. G. R. Blakely, who was Chairman for the Weekend School, and to Mr. R. E. Leakey and Mr. W. F. S. Woodford for their support during the weekend. All those present at the School enjoyed a thoroughly profitable and sociable weekend including the Saturday evening in the local, which has now become a regular feature of the Schools.

South Essex

The winter programme commenced with the meeting at Chelmsford, in October, when Mr. R. Harle, Secretary of the Production Department of the T.U.C., gave a very provocative talk on the " Trade Unions and Industrial Development ".

At Ilford, in November, Dr. Farthing gave his Paper " New Metals " to a good audience, but the December meeting was disappointing in that very few members were able to attend because of petrol restrictions. This was doubly regrettable as Mr. Bray, of B.A.C.I.E., speaking on " Future Trends in Technical Education ", gave what many consider to be one of the best talks ever given at Chelmsford.

The President, Mr. E. W. Hancock, M.B.E., kindly accepted the Section's invitation to take the Chair at the January meeting, when there will be a lecture on "Electronic Computers " by Mr. D. T. N. Williamson, of Ferranti Ltd.

At the last Committee meeting three additional members were co-opted to the Committee in order to strengthen it and broaden its representation. Two Regional matters were discussed, the Section Committee supported the South Eastern Region's three-point proposal on Papers from Graduates, but rejected for the time being the suggestion that the Section should be renamed the Chelmsford Section.

SOUTH WESTERN REGION

Western

The Western Section were honoured to be selected as the venue for the 1956 Viscount Nuffield Paper. Dr. Grey Walter gave a very stimulating Paper to a large and representative audience.

The Annual Dinner and Dance unfortunately clashed with one or two national functions and, consequently, numbers were much reduced. However, what was lacking in quantity was made up for in quality, and the Section was extremely pleased that the President and his wife were able to be present, together with Mr. and Mrs. Woodford. It can be said that an enjoyable time was had by all.

The lectures so far have been most interesting and instructive ; the Nuffield Paper has already been mentioned: the lecture on " The Building of the Dido Atomic Reactor " was most ably given by Mr. W. F. Wood. The December lecture was a joint one with the local branch of the Royal Aeronautical Society and was given by Mr. P. G. Masefield. The meeting was a great success and it is hoped to hold joint meetings of this nature in the future.

WELSH REGION

Regional Report

The Chairman, Mr. W. H. Bowman, and the Regional Committee recently paid tribute to the excellent work the

past Chairman, Mr. W. Abraham, did during his term of office.

A very informative lecture on "Higher Technological Education" and how it might be achieved, was given by Dr. Richmond, at Cardiff, and proved highly successful. As a result it was felt that the Institution of Production Engineers' efforts to promote the training of technical officers in South Wales had been considerably enhanced.

In addition, under the new constitution of the Cardiff College, the Institution would, without doubt, be represented on the Advisory Committee and it is hoped at a later date to have representation on the Board of Governors.

The Committee are now actively engaged in investigating the possibilities of holding a One-Day Convention in the near future, which would be of interest to the rather wide field covered by local industry.

The publication of a combined Calendar of Engineering and Allied Professional Institutions in South Wales provides in one document a programme of the meetings of all participating professional bodies. In view of the wide area covered by the Region, it is considered that this Institution's programme should also in the future be incorporated.

South Wales and Monmouthshire

During the past quarter the lecture programmes have been very well attended and have promoted considerable interest and discussion. One lecture on "Training of the Production Engineer" given by Dr. W. A. J. Chapman, was of particular interest to the Section in view of the Committee's efforts in obtaining improved educational facilities for the production engineer in South Wales.

Dr. Chapman stressed the necessity for students to obtain training in administration and central government in addition to that of production engineering. This broader conception of training of production engineers would undoubtedly give much higher status to the production engineer.

In addition, representation has been requested for a member of the Institution on the Governing Board of the Cardiff College of Technology and also the Advisory Committee for Engineering and this is being given consideration by the Director of Education, Cardiff.

The Committee are most anxious to do all in their power to ensure that a comprehensive training is available in production engineering and it is hoped that steps already taken will do much to eliminate the dire shortage of production engineers in the area.

SECTIONS OUTSIDE THE UNITED KINGDOM

Calcutta

An interesting lecture was held in December when Mr. Abraham Leonard Raich, M.Sc.(Wash.), Statistical Quality Control Expert, spoke on "How a Statistician Looks at Engineering Problems".

Three Section Committee meetings were held during the quarter under review.

Melbourne

In keeping with the Institution's policy of "Broadening the Base", the Melbourne Section meeting in September had a Paper on a subject outside the engineering field, namely, "Production Methods in Boot and Shoe Manufacture" presented by Mr. F. Finkler, a Director of British United Shoe Machinery Company, of Australia. However, it would appear that, generally speaking, members are not interested in subjects outside the engineering field.

Following this meeting, a works visit was held to the Julius Marlow shoe factory. Twenty members attended and were shown the processes involved in shoe manufacture.

The Annual Meeting was held in October and Mr. J. Steer, M.I.Prod.E., was elected Chairman for the year 1957. Mr. E. J. Herbert was re-elected Vice-Chairman.

After the meeting a Paper entitled "Overseas Machine Tools Shows" was presented by Mr. J. Steer. Eighty-six members were in attendance and were very interested in this Paper, which covered the 1955 Chicago Machine Tool Show, the 1956 London Olympic Show and the 1956 Milan Fair.

The Section's Annual Dinner was held in November at the University of Melbourne, when the guest speaker was the Honourable J. S. Bloomfield, M.L.A., Minister for Education, who spoke on "Technical Education in Victoria". The Dinner was most successful, with an attendance of 130 members and friends.

Melbourne Graduate

Works Visit to Radio Corporation Ltd.

In September, the Section visited Radio Corporation Ltd., South Melbourne, who are one of Australia's largest manufacturers of television equipment. The manufacture of television units in complete detail were shown, with particular emphasis on the application of time standards in production. This visit was particularly interesting and was attended by 23 members.

Annual Meeting

The Section Annual Meeting was held in October at the Royal Melbourne Technical College, and the following officers were elected for 1957: Chairman, Mr. P. J. W. Cottrell; Secretary, Mr. F. A. Roberts; Publicity Officer, Mr. K. Stevenson; Visits Secretary, Mr. B. Davies; and Film Secretary and Registrar, Mr. D. McKelvie.

Programme for 1957

The programme for 1957 was confirmed by the new Committee early in December, 1956.

New Zealand

During this quarter two visits to production plants in the Auckland district were arranged for members and their friends. At the first of these plants, New Zealand Forest Products Ltd., the processing of pinewood chips into Pinex Board and Hardboard was witnessed.

At the second plant, Reid New Zealand Rubber Mills Ltd., the processing of raw rubber is carried out to the final production of tubeless tyres, etc. Both of these visits were well patronised and appreciated by the members and the earnest co-operation of executives of the firms approached in organising these visits so efficiently and smoothly is also appreciated by the Section and deserves commendation.

Three Committee meetings have been held and following one of these a Film Evening for members and friends to witness a screening of films dealing with the application and uses of Stellite — kindly loaned by the local distributor of that product.

South Africa

In September, the first meeting of the new Session took the form of a discussion evening with members of the Johannesburg Branch of the Institute of Cost and Works Accountants. Many points of mutual interest were raised, and it was unanimously agreed that both associations could benefit from greater co-operation and a closer understanding of each other's aims and problems.

The opportunity was taken in October to invite members, their wives and friends to a social evening, during which Mr. H. G. Goyns, the Immediate Past President, gave a most interesting talk — illustrated with colour films and slides — on his recent safari to the Kilimanjaro area. This proved an exceptionally popular evening, attended by well over 100 members and friends and everyone eagerly awaits a similar production from Mr. Goyn's next trip.

Early in November, members visited the workshops of the new Jan Smuts International Airport, to hear a lecture by Mr. Trevor Philips on "Inspection Methods". This was followed by a comprehensive tour of all workshop departments and an inspection of the newest South African Airways plane, the Douglas DC-7-B. In conclusion, members were entertained to tea by Col. Louw, the General Manager of South African Airways.

For the December meeting, a joint visit to the new factory of Messrs. Norton Abrasives was arranged with the Institute of British Foundrymen. Over 100 members attended what was subsequently voted a most interesting instructive and enjoyable evening. All departments of the works were visited and members were impressed not only with the processes and methods employed, but also with the efficiency and obvious enthusiasm with which the visit was organised and controlled by the Norton staff.

As is usual in South Africa, no meetings are scheduled for January, but the Council and the Papers Committee has a very full and varied programme planned for 1957.

institution notes

The Late Tom Fraser, C.B.E. — An Appreciation

In the passing of Tom Fraser the Institution has lost one of its best friends. All who had the good fortune to know him will remember him as a gentle and kindly man who was ever ready to give of his vast experience. He was already well established in his professional life when he joined the Institution in 1931. His service to the Institution began in the first day of his membership, when he joined the Committee of the Manchester Section. He was Section President from 1932 to 1945 and he continued to serve the Manchester Section until his retirement to Conway in 1947, but even after his retirement he maintained an active interest in the Section activities. He was affectionately regarded as the " Father " of the Manchester Section and it is in Manchester that his loss will be most keenly felt.

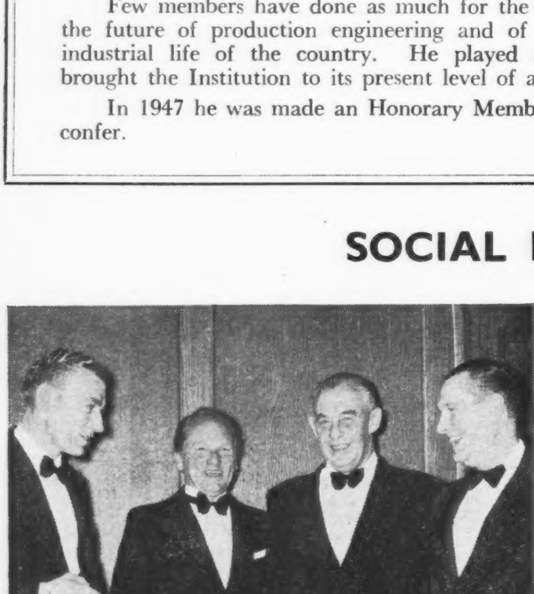
He was elected to the Council of the Institution in 1932 and was Chairman of Council from 1934 to 1936. Apart from a brief interlude, he remained a member of Council until his death. He was elected a Trustee of the Institution in 1945.

He was an engineer of considerable distinction and for the greater part of his life he was in the service of Metropolitan-Vickers. He was 44 years with this great Company and in 1944 he was made a Director. He was one of the group of British engineers who were sent to Russia to give technical assistance to the U.S.S.R., and he remained in that country for more than a year. During the Second World War he was in charge of the Metropolitan-Vickers aircraft works at Trafford Park, for which work he was awarded the C.B.E.

Few members have done as much for the Institution as Tom Fraser. He had a clear vision of the future of production engineering and of the part which the Institution should play in the industrial life of the country. He played a prominent part in shaping the policy which has brought the Institution to its present level of activity.

In 1947 he was made an Honorary Member, which is the highest honour the Institution can confer.

SOCIAL FUNCTIONS



Above : This happy group were photographed at the recent Annual Dinner of the South African branch. From left are the President of the South African Council, Mr. D. S. Clare ; the immediate Past President, Mr. H. J. G. Goyns ; Mr. D. Lion-Cachet, also a Past President ; and a principal guest, Mr. Charles Bedaux, Managing Director, International Management Consultants (Pty.) Ltd.

Below : The Annual Dinner of the Wolverhampton Section, held on 18th January last, was obviously another enjoyable occasion. In the photograph are (from left) Mr. Leslie Farrer, Wolverhampton Section Committee ; Mr. G. A. Firkins, Chairman of the Wolverhampton Section ; Mr. Harold Burke, Past Chairman of Council ; Mr. E. W. Hancock, M.B.E., President of the Institution, and Guest of Honour ; Mr. F. C. White, Member ; and Mr. W. V. Hedgson, Member.

Mr. J. D. Pearson, Member, is now a Deputy Chairman of Rolls-Royce Limited and is responsible for the Company's activities, in addition to continuing as Managing Director of the Aero-Engine Division at Derby. Mr. Pearson is a B.Sc.(Eng.) and a Senior Whitworth Scholar, a Member of the Institution of Mechanical Engineers, and an Associate Fellow of the Royal Aeronautical Society. He joined the Company 24 years ago, working first on aero-engines design and then in the experimental department and as materials engineer. When the Second World War broke out, Mr. Pearson became Chief Technical Production Engineer at Glasgow. After the War he established the Rolls-Royce Technical Office in Montreal, which has now become a subsidiary Company, Rolls-Royce of Canada. He then worked as Chief Service and Quality Engineer in Britain until he became General Sales and Service Manager of the Aero-Engine Division. He became Deputy General Manager of the Aero-Engine Division and joined the Board in 1929. Since then he has been successively General Manager and Managing Director of the Aero-Engine Division.

Mr. H. P. Bhadury, Associate Member, has recently taken up an appointment as Principal of the Central Training Institute of the Associated Cement Companies Limited, Kymore (M.P.), India.

Mr. D. V. Borgaonkar, Associate Member, Deputy Superintendent in the Central Workshops at Poona of the Bombay State Road Transport Corporation, has been training in Britain under a United Nations Scheme, making a special study of diesel engines.

Mr. L. J. Daughtrey, Associate Member, has taken up a position with the Atomic Weapons Research Establishment, Aldermaston.

Mr. F. A. Eastwood, Associate Member, has taken up an appointment at Hackney Technical College as Responsible Lecturer in Mechanical Engineering and has consequently relinquished his position at the South-East London Technical College.

Mr. J. Ekins, Associate Member, in his capacity as Supervisor of Management Studies at Sheffield College of Commerce and Technology, has now been re-graded from Lecturer to Senior Lecturer.

Mr. T. H. Fraser, Associate Member, has now joined Messrs. Scottish Precision Castings Limited, as Production Manager.

Mr. R. Gore, Associate Member, has relinquished his position as General Manager of Sheepbridge Equipment Limited, Chesterfield, and has taken up a position as Works Director with Messrs. Acrow (Engineers) Limited, at Saffron Walden, Essex.

Mr. W. A. Maw, Associate Member, has recently been appointed to the position of Superintendent of Technical and Industrial Departments with H. C. Sleigh Limited, Melbourne, Australia.

Mr. L. E. Overton, Associate Member, has now taken up the appointment of Production Engineer with Northern Electric Co. Limited, Montreal, Canada.

Mr. K. D. Park, Associate Member, has relinquished his position as Development Engineer with Exactor Limited, and has now taken up a similar appointment with Dowty Hydraulics Limited.

Mr. G. M. Ranson, Associate Member, is relinquishing his position as Chief Engineer with John Wright and Co. Ltd., Birmingham, to take up a new appointment as Personal Assistant to the Works Director, Audley Engineering Co. Ltd., Shropshire. Mr. Ranson serves on the Materials Handling Sub-Committee of the Institution's Research Committee.

Mr. H. J. Richards, Associate Member, has been appointed Production Manager of Flexibox Limited, Trafford Park, Manchester. He is responsible for production at Trafford Park and Ballymena Works, Northern Ireland.

Mr. S. J. Sterrett, Associate Member, has recently relinquished his position with Elliott Brothers (London) Limited, and has taken up an appointment as a Mechanical Development Engineer on the Scientific Staff of the National Institute for Medical Research.

Mr. H. G. Thomas, Associate Member, Resident Engineer, Davy-United Limited, Sheffield, following the completion of the Norsk Jeruverk plant in Norway, is now commencing the erection of similar rolling mills in Avilés, Spain.

Mr. P. O. Fabiyi, Associate, has recently been promoted to the position of Industrial Officer (Design), in the Western Regional Government of Nigeria.

Mr. A. L. Cole, Graduate, is now a Design Engineer with the Boeing Airplane Company, Seattle, Washington, U.S.A.

Mr. J. D. Collins, Graduate, has now left the de Havilland Engine Company and has taken up a position with the Bristol Aero-Engine Company in their Licence Office.

Mr. R. Holyoake, Graduate, who was Senior Draughtsman at British Celanese Limited, has now been appointed Assistant Instrument Engineer.

Mr. E. I. Martin, Graduate, has now been appointed Factory Quality Controller at the Merton branch of the Metal Box Company.

Mr. W. G. Peters, Graduate, has recently taken up an appointment as Project Engineer with the Metal Box Company Limited, Technical Engineering Division, Willesden.

Mr. G. Yates, Graduate, has taken up a new appointment as Assistant Grade " B ", responsible for the engineering workshops at the Walker Technical College, Oakengates, Shropshire.

CORRECTION

In the February issue, a reference to Mr. J. G. Crofts was, unfortunately, confused with a reference to Mr. D. M. Sen. The announcements should have read as follows :-

Mr. D. M. Sen, Member, who was Works Manager of Messrs. Burn & Co. Limited, Howrah, Calcutta, has been appointed Deputy General Manager.

Mr. J. G. Crofts, Graduate, is now Service Manager at Triplejay Equipment (Rhod.) (Pvt.) Limited, Salisbury, Southern Rhodesia.

Obituary

The Institution records with deep regret the death, on 12th November last, of **Mr. H. J. Bavington,** Member, of Rotax Ltd., Willesden.

Mr. Bavington was a founder member of the Institution and at all times loyally supported its aims and activities. His profound knowledge of production engineering, and his achievements during 41 years with Rotax Ltd., are well-known to his many business friends.

Apart from the respect which his ability created, his kind and generous nature, combined with a never-failing sense of humour, endeared him to everybody who came into contact with him.

It is good to be able to record that in spite of the many periods of intense suffering occasioned by his illness, these outstanding qualities remained with him to the end. B.W.M.W.

RESEARCH PUBLICATIONS

A number of copies of the following Research publications are still available to members, at the prices stated :

Machine Tool Research and Management	10/6
Report on Surface Finish, by Dr. G. Schlesinger	15/6
Practical Drilling Tests	21/-

These publications may be obtained from the Production Engineering Research Association, " Staveley Lodge ", Melton Mowbray, Leics.

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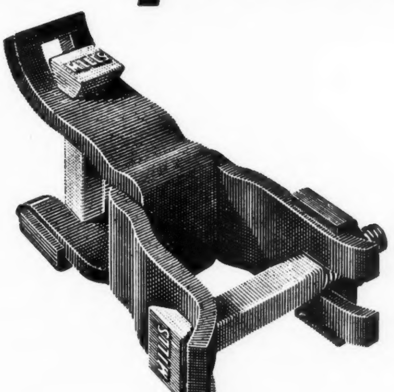

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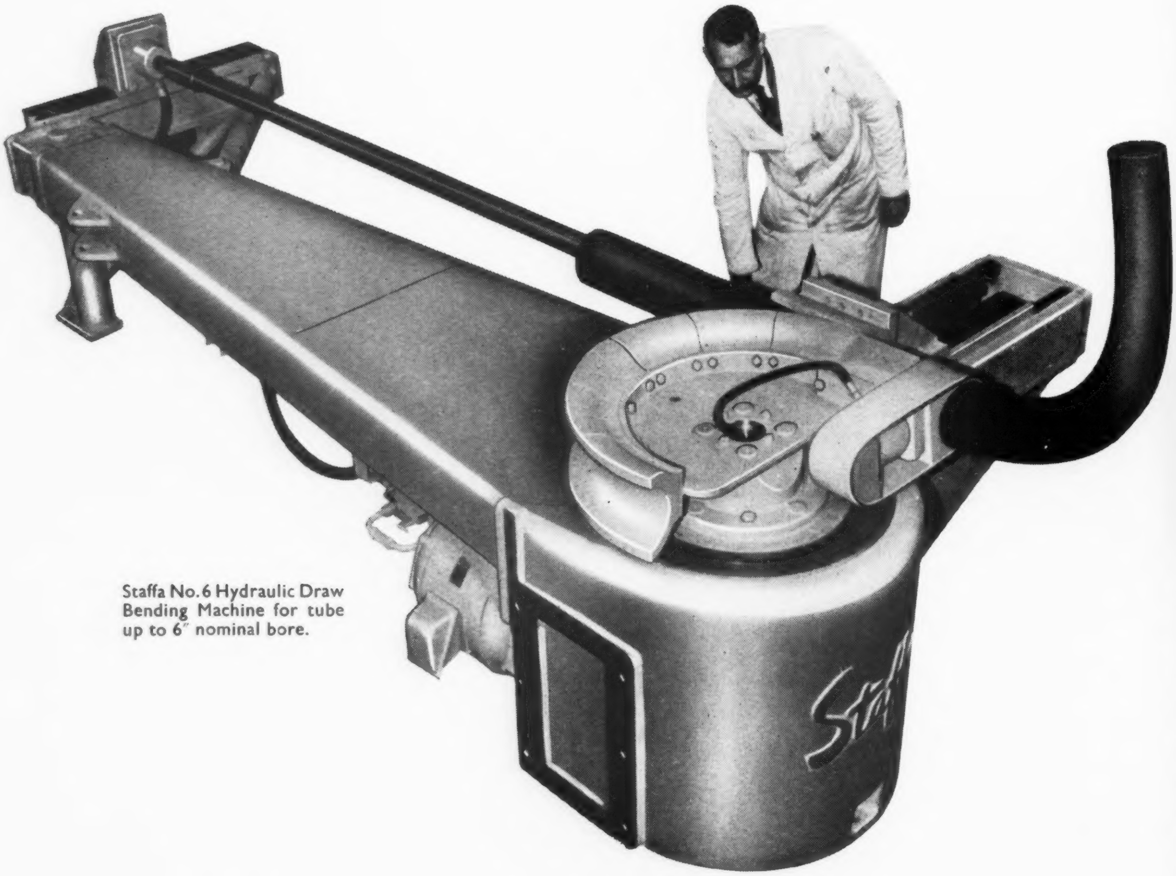

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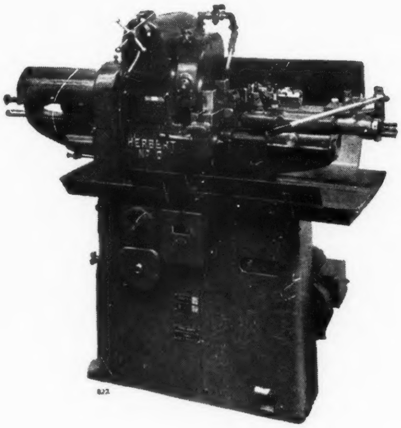

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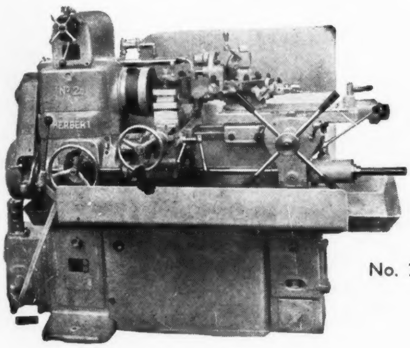

No. 2D

No. 2D *For bar work up to 1½" and chuck work up to 9" swing. Ideal for work involving frequent changes of set-up. Sixteen speeds,* 50 - 2,550 *r.p.m.* 4-*speed motor,* 3/3/3/2½ *h.p. Three rates of automatic feed for capstan slide.*

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Spindle flange to capstan, max.	18¾" *or* 26¾"

No. 2 Flashcap *For high production of non-ferrous threaded parts requiring frequent spindle reversals.* 6" *air-operated chuck. Twelve speeds,* 158 - 2,660 *r.p.m.*

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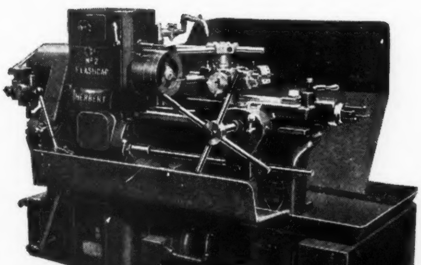

No. 2 FLASHCAP

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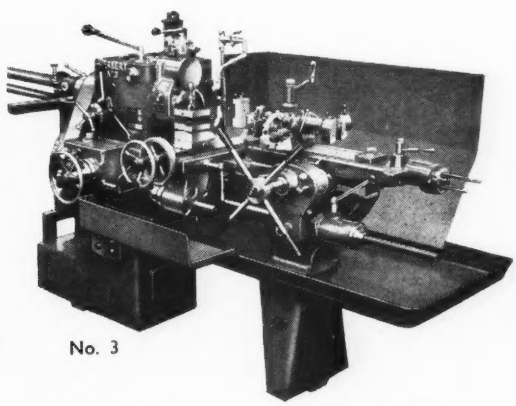

No. 3

On receipt of drawings or sample components we will give estimates of production and quote for suitable equipment.

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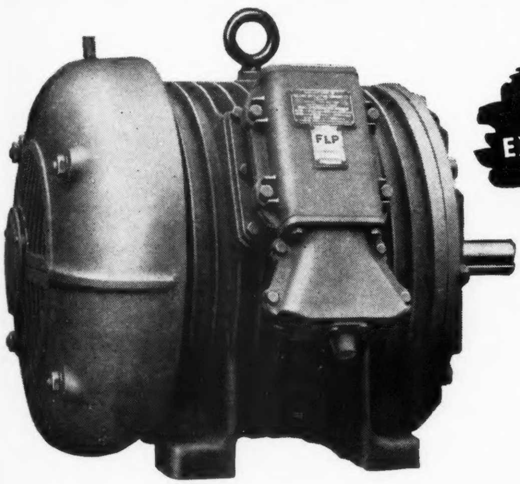

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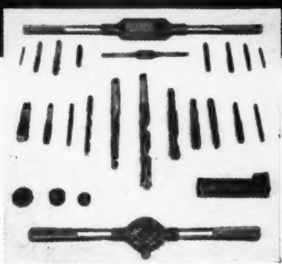


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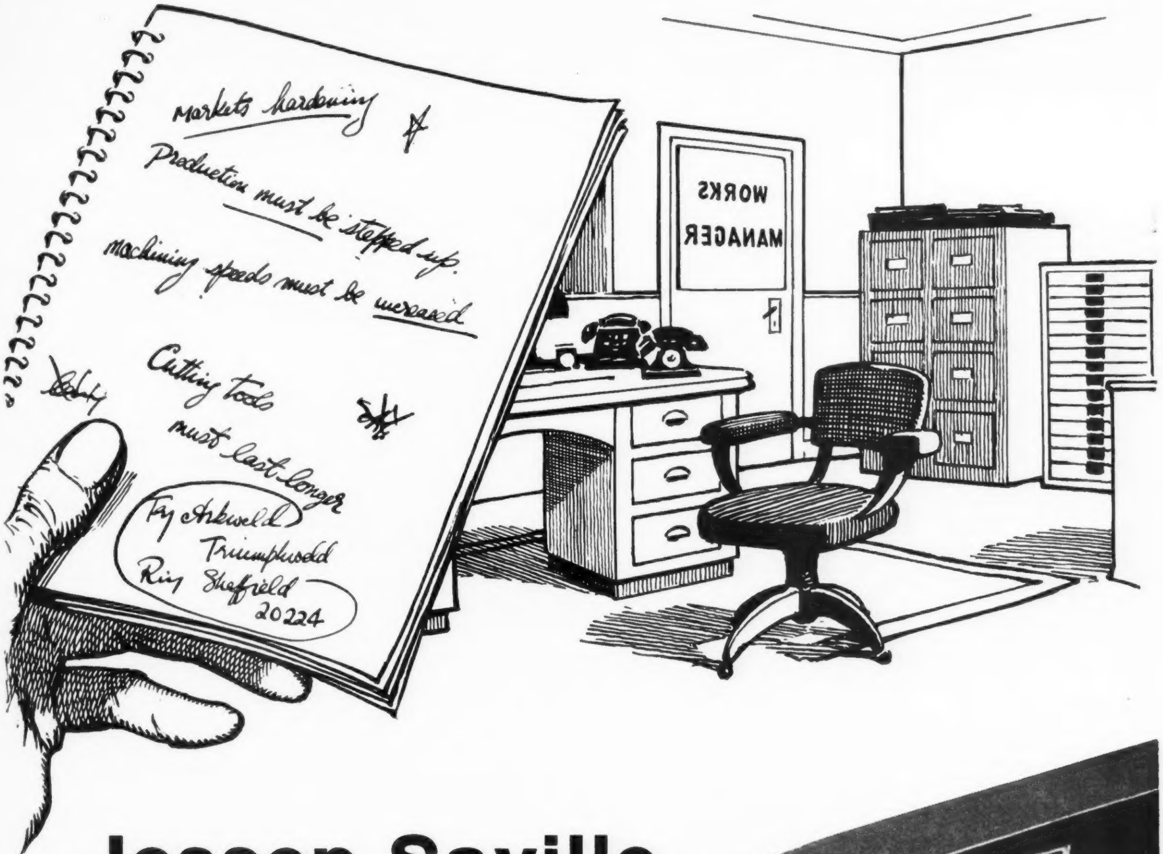

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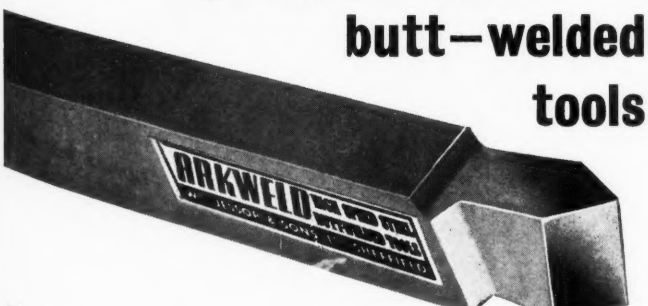

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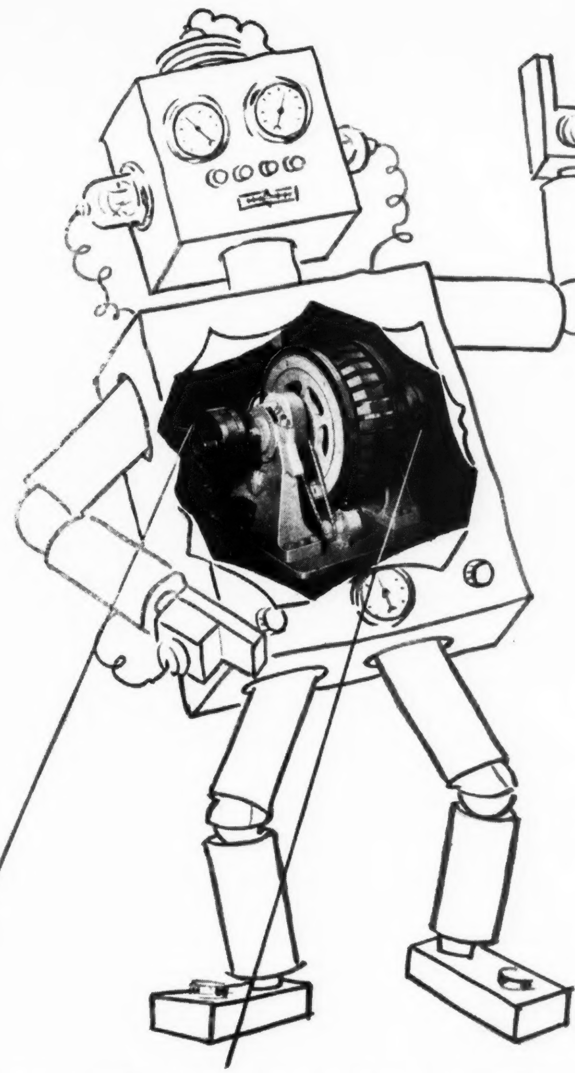

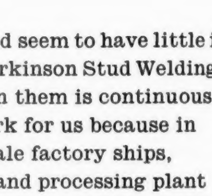

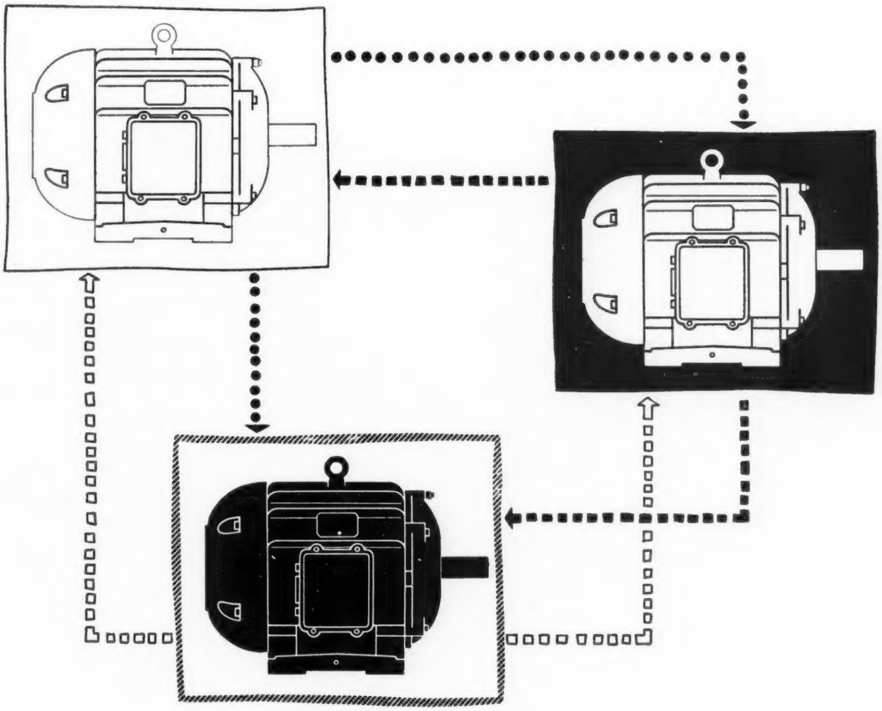

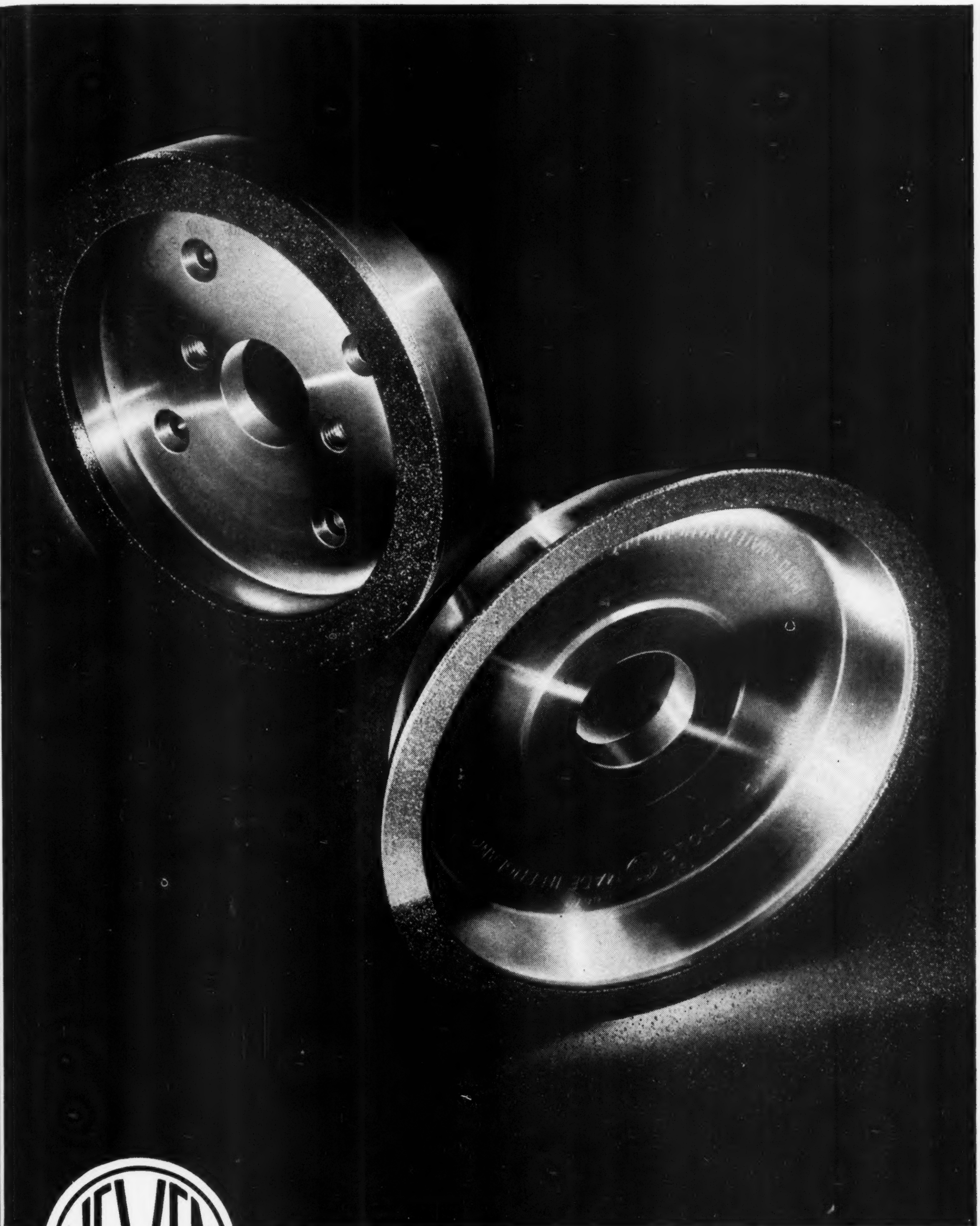

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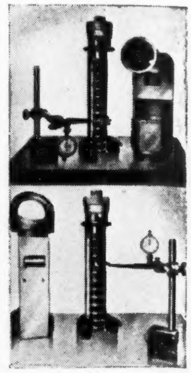

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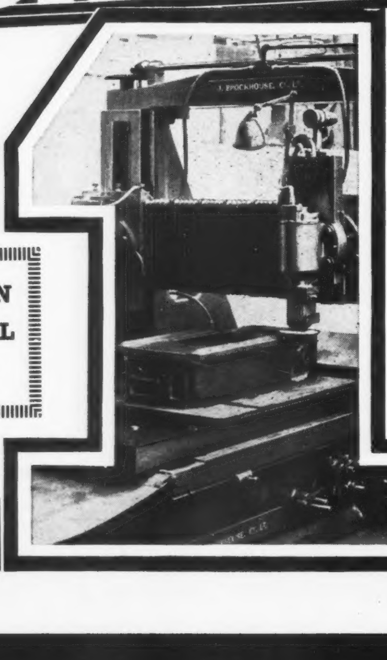

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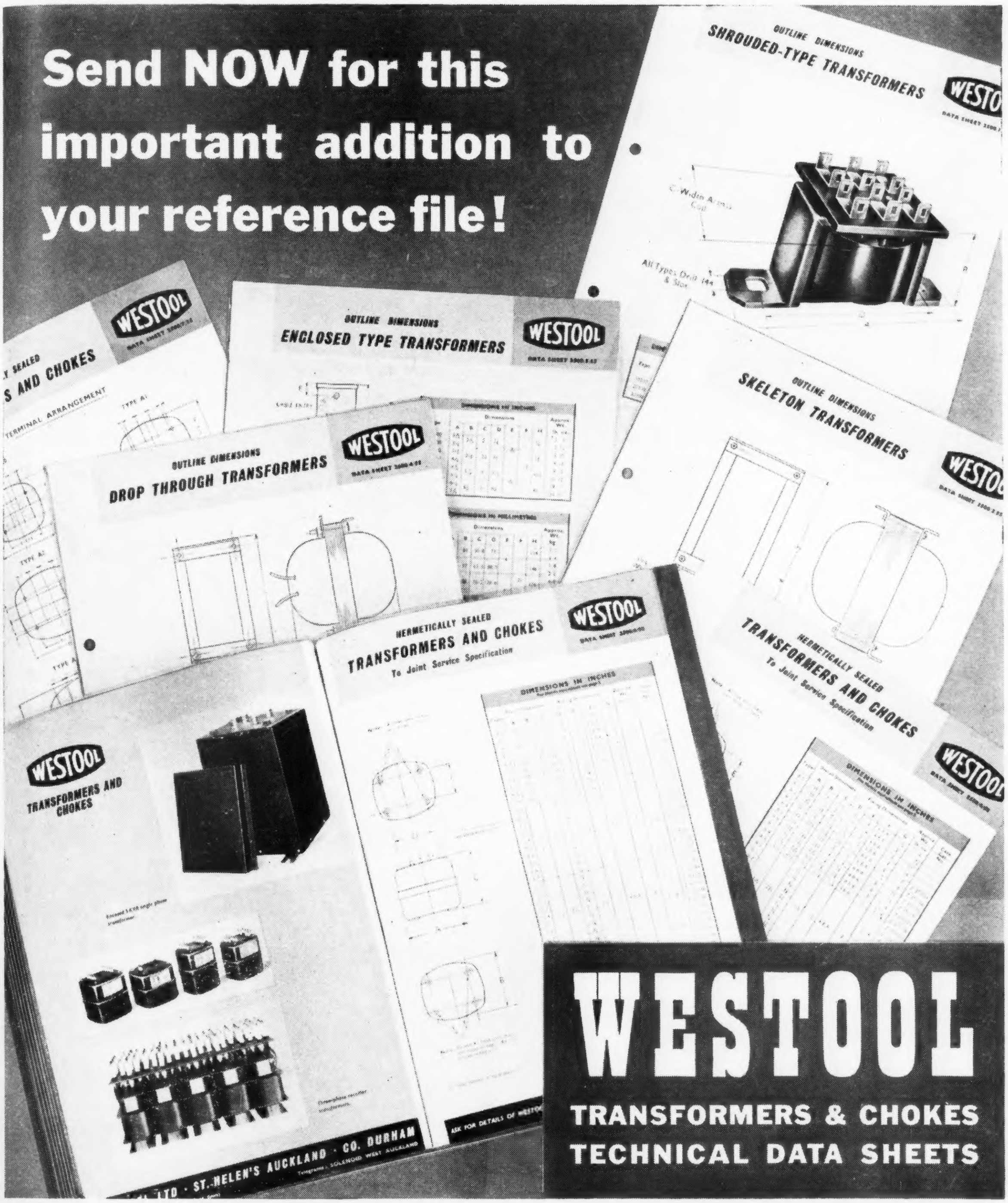

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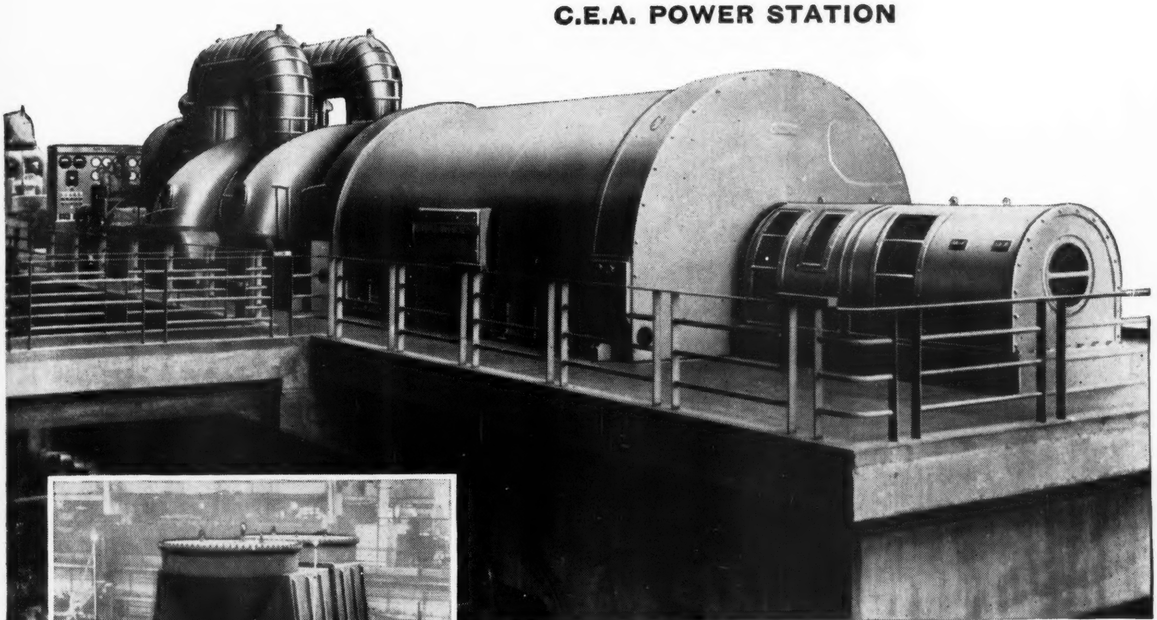

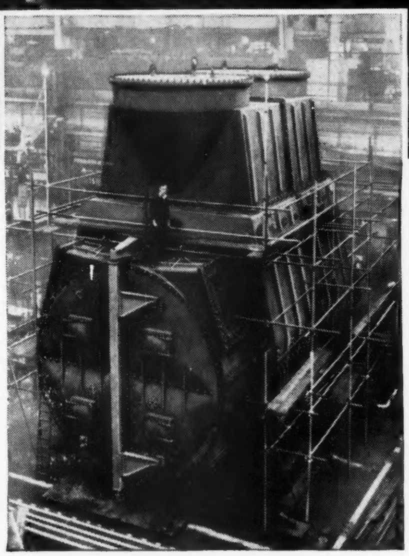

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The illustration shows a single-shell condenser under construction. Six of these units, each having a cooling surface area of 60,000 sq. ft., are being supplied for the installation.

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